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A., Rodney [AU/AU]; Dept. of Primary Industries, 80 Ann Street, Brisbane, QLD 4000 (AU). JONES, J., Lee [AU/AU]; Dept. of Primary Industries, 80 Ann Street, Brisbane, QLD 4000 (AU). BARKER, R., Leigh [AU/AU]; Dept. of Primary Industries, 80 Ann Street, Brisbane, QLD 4000 (AU).

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(74) Agent: MCMASTER OBERIN ARTHUR ROBINSON & HEDDERWICKS; Stock Exchange Centre, 530 Collins Street, Melbourne, VIC 3000 (AU).

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(71) Applicant (for all designated States except US): MIT-SUBISHI AUSTRALIA LIMITED [AU/AU]; Level 36, 120 Collins Street, Melbourne, VIC 3000 (AU).

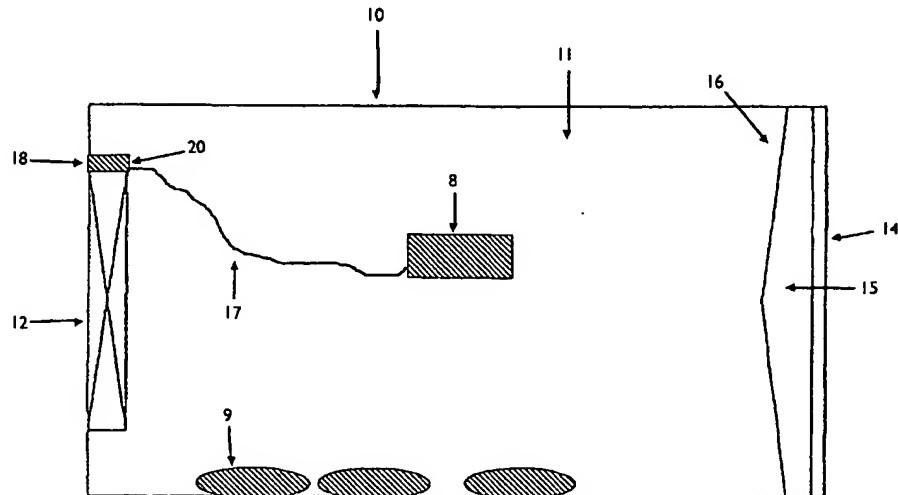
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(54) Title: APPARATUS AND METHODS FOR CONTROLLED VENTING OF A CHAMBER



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(57) Abstract: Apparatus and method for adjusting the atmosphere within a partially sealed chamber containing respiring produce. The chamber has openings to permit ambient atmosphere to enter (11) and chamber atmosphere to exit through a valved port (18, 20). The apparatus is provided with monitors and sensors (8) for detecting oxygen concentration amounts, and control means (7) for causing ambient atmosphere to enter the chamber when oxygen falls below a predetermined amount. Carbon dioxide is removed at a predetermined rate such that the carbon dioxide concentration within the chamber atmosphere does not substantially exceed a predetermined amount. The rate of removal of carbon dioxide is calculated using a mathematical formula and the carbon dioxide removal is effected by contacting absorbing material (9) in a container within the chamber. The chamber has a fan (12) to provide high and low sources of pressure for creating a chamber atmosphere pressure above or below ambient pressure.

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## APPARATUS AND METHODS FOR CONTROLLED VENTING OF A CHAMBER

### Field of the invention

The present invention relates generally to the delay of deterioration of perishable products

- 5 by the management of the composition of the atmosphere in contact with the product and to apparatus and methods therefor.

### Background of the invention

Many items of perishable produce respire after harvest. That is they consume oxygen and

produce carbon dioxide. It is known that if the rate of respiration can be slowed during

- 10 transportation, the produce will degrade less. The rate of respiration can be controlled by controlling the amount of oxygen and/or carbon dioxide available to the produce.

Many items of produce deteriorate after removal from the plant. This deterioration which

is usually given the term senescence, can be delayed by enclosing the perishable product in a chamber to which is applied well recognised methods, such as reduction of temperature

- 15 below ambient room temperature, and/or the reduction of the concentration of oxygen below that occurring in air, and/or the elevation of the concentration of carbon dioxide above the concentration occurring naturally in air. Each of these conditions may be applied alone or in combination with any or all of the others.

However if the oxygen concentration is reduced too much or the carbon dioxide

- 20 concentration rises too high, then the perishable product may be injured, resulting in even more rapid deterioration than might occur if no treatment was applied. Consequently it is desirable to be able to adjust the composition of the atmosphere within the chamber and apparatus and methods for adjusting the atmosphere in the chamber have accordingly been developed.

- 25 For transportation of perishable produce, the chamber referred to may be a shipping container, which in a common form may be fitted with a refrigeration system to adjust the temperature.

Controlled atmosphere containers are usually purpose built. However, controlled

atmosphere apparatus may also be installed in a refrigerated container following a

- 30 time-consuming and expensive operation.

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In one existing apparatus for controlling the atmosphere in a container, the atmosphere is taken from the container and passed through a device for actively modifying the atmosphere such as a carbon dioxide absorption tower and the modified atmosphere reintroduced into the container. The various devices for actively modifying the container atmosphere are expensive and generally difficult to service during transportation.

Where such apparatus is to be used to convert a refrigerated container to a controlled atmosphere container, holes may need to be made in the container walls to allow the container atmosphere to be drawn from the container to be modified and returned to the container. Such a process may need a permanent modification to be made to a refrigerated container and would be time consuming and expensive.

#### **Summary of the invention**

According to a first aspect of the present invention there is provided a method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following step (b), the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter the chamber and an opening to permit chamber atmosphere to exit the chamber, the method comprising:

- (a) monitoring the oxygen concentration within the chamber; and
- (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing chamber atmosphere to exit the chamber through an opening so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening so that the amount of oxygen in the chamber is or will be increased.

The chamber must be open to the stated extent in order for sufficient oxygen to be drawn into the chamber to be able to maintain the oxygen concentration in the chamber within an appropriate tolerance of the predetermined amount while the respiration of the respiring

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produce reduces the oxygen concentration within the chamber. The chamber must be sealed to the stated extent to prevent the oxygen concentration in the chamber from rising above an appropriate tolerance of the predetermined amount through leakage of ambient atmosphere into the chamber.

- 5 The opening to permit ambient atmosphere to enter the chamber may be the same opening as the opening to permit chamber atmosphere to exit the chamber. However, it is preferred that a distinct opening is provided in the form of an openable and closeable outlet means to permit chamber atmosphere to exit the chamber.

Chamber atmosphere may be caused to exit the chamber through an opening by locating

- 10 the opening near a source of high pressure inside the chamber, such that chamber atmosphere is expelled from the chamber through the opening. The source of high pressure may be supplied by a fan. In an embodiment where the chamber is formed within a refrigerated container having a refrigeration fan inside the chamber, the refrigeration fan may be used as a source of high pressure.

- 15 Chamber atmosphere may be caused to exit the chamber through an opening by locating the opening near a source of low pressure outside the chamber, such that chamber atmosphere is drawn out of the chamber through the opening. The source of low pressure may be supplied by a fan.

- An opening for permitting ambient atmosphere to enter the chamber may be provided  
20 wholly or partly by leakage paths into the chamber. An opening may be added to the chamber, such as by making one or more holes in the chamber. An opening may comprise existing leakage paths into the chamber.

- In the embodiment where the opening for permitting ambient atmosphere to enter the chamber is the same as, or one of, respectively, the opening or openings for permitting  
25 chamber atmosphere to exit the chamber, ambient atmosphere may be drawn into the chamber through the opening following turning off the source of high or low pressure (as the case may be), or removing it from the vicinity of the opening, so that when the pressure in the chamber is below ambient pressure, ambient atmosphere may be drawn into the chamber through the opening.

Sealing means may be applied to the chamber such that the chamber is sealed to the required extent ie such that when the pressure within the chamber is substantially equal to ambient pressure the rate of entry of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce.

- 5 Preferably, the method further comprises the step of removing carbon dioxide from the chamber atmosphere substantially at a predetermined rate, the predetermined rate having been selected such that the carbon dioxide concentration within the chamber atmosphere does not substantially exceed a predetermined amount.

In an embodiment including outlet means, the method may further provide for the outlet 10 means to be open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

The method may further provide for the predetermined carbon dioxide removal rate to be calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere subject to the requirement that the oxygen concentration within the 15 chamber be substantially maintained at a predetermined amount. The predetermined carbon dioxide removal rate is preferably calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

20 where  $a_{O_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

The method may further provide for at least part of the carbon dioxide removal to be 25 effected by contacting a quantity of carbon dioxide absorbing material with the chamber atmosphere. The carbon dioxide absorbing material is preferably contained in at least one carbon dioxide transmissible container, such as for example a carbon dioxide transmissible bag. Preferably, the at least one carbon dioxide transmissible container is selected so that

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the rate of carbon dioxide transmission into the at least one carbon dioxide transmissible container is substantially equal to the predetermined carbon dioxide removal rate.

According to a further aspect of the present invention there is provided a method for converting a receptacle into an adjusted atmosphere chamber for containing respiring

5 produce, the method comprising:

(a) forming a chamber in the receptacle that is sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, and which is open to the extent that when the chamber

10 pressure is less than ambient pressure following a chamber pressure reduction as described in step (e) the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce;

(b) optionally, installing sealing means so as to seal the chamber to the required extent;

(c) optionally, installing an opening in the chamber to permit ambient atmosphere to 15 enter the chamber;

(d) installing an opening to permit chamber atmosphere to exit the chamber;

(e) 20 installing a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause chamber atmosphere to exit the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening in the chamber so that the amount of oxygen in the chamber is or will be increased.

25 As above, the opening to permit ambient atmosphere to enter the chamber may be the same opening as the opening to permit chamber atmosphere to exit the chamber. However, it is preferred that a distinct opening is provided in the form of an openable and closeable outlet means to permit chamber atmosphere to exit the chamber.

The control means may cause chamber atmosphere to exit the chamber through the 30 opening by locating the opening near a source of high pressure inside the chamber, or a

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source of low pressure outside the chamber. In the case where an opening in the form of an outlet means is used, if the outlet means is always located near a source of high or low pressure, as the case may be, then the control means may cause chamber atmosphere to exit the chamber through the outlet means by opening the outlet means.

- 5 The method may further include the step of installing carbon dioxide removal means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate whereby the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce. The method may further provide for the predetermined  
10 carbon dioxide removal rate to be calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere subject to the requirement that the oxygen concentration within the chamber be substantially maintained at a predetermined amount. The predetermined carbon dioxide removal rate is preferably calculated from a formula that produces a result substantially equal to the result produced by the  
15 aforementioned formula.

The method may further provide for the outlet means to be open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

- According to a further aspect of the present invention there is provided a receptacle when  
20 converted into an adjusted atmosphere chamber in accordance with the methods for converting a receptacle into an adjusted atmosphere chamber described herein.

- According to a further aspect of the present invention there is provided apparatus for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal  
25 to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following a chamber pressure reduction as described below, the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce, the apparatus comprising a  
30 controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause chamber

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atmosphere to exit the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening in the chamber so that 5 the amount of oxygen in the chamber is or will be increased.

Preferably, the apparatus includes openable and closeable outlet means to permit chamber atmosphere to exit the chamber. In this embodiment, the control means is adapted to cause the outlet means to open to cause chamber atmosphere to exit the chamber. In this embodiment, a source of high pressure inside the chamber, or of low pressure outside the 10 chamber, is provided. Such a source of high or low pressure may be part of the apparatus of the present invention, but is not essential, as the chamber may already have a readily useable source of pressure, such as a refrigeration fan inside the chamber.

The apparatus may include sealing means for sealing the chamber to the required extent.

Preferably, the apparatus also includes carbon dioxide reduction means adapted to remove 15 carbon dioxide from the chamber atmosphere substantially at a predetermined rate so that, in use, the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce.

The controller may be further adapted to cause the outlet means to remain open for a time 20 that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

The apparatus may include outlet means that comprise one or more electromagnetically actuable valves having a solenoid so that the one or more valves may be opened from a closed position and closed from an open position by applying direct electric current to the 25 solenoid, the one or more valves being held in either the open position or the closed position in the absence of the application of the direct electric current.

According to another aspect of the present invention, there is provided a method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal 30 to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of

consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following step (b), the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter

- 5 the chamber, and an opening to permit chamber atmosphere to exit the chamber, the method comprising:

- (a) monitoring the oxygen concentration within the chamber;
- (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing chamber atmosphere to exit the chamber through an opening so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening so that the amount of oxygen in the chamber is or will be increased; and
- 10 (c) prior to steps (a) and (b), selecting an oxygen setpoint such that steps (a) and (b) cause the carbon dioxide concentration within the chamber atmosphere to not substantially exceed a predetermined amount.
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The opening for permitting chamber atmosphere to exit the chamber may be an openable and closeable outlet means as described above.

- According to an aspect of the present invention there is provided a method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter the chamber, and an opening to permit chamber atmosphere to exit the chamber, the method comprising:
- 20

- 25 (a) monitoring the oxygen concentration within the chamber; and
- (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing ambient atmosphere to enter the chamber through an opening so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such

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that chamber atmosphere is or will be expelled from the chamber through an opening;

the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following step (b) the rate of leakage of chamber atmosphere out of the 5 chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber again falls below the predetermined amount, to a level that will not prevent ambient atmosphere from entering the chamber through the opening first referred to in step (b).

The chamber must be sealed to the stated extent to prevent the oxygen concentration in the 10 chamber from rising above an appropriate tolerance of the predetermined amount through leakage of ambient atmosphere into the chamber. The chamber must be open to the stated extent in order to allow the pressure within the chamber to be reduced sufficiently quickly through leakage of chamber atmosphere out of the chamber that the chamber pressure has reduced to a level that will not prevent ambient atmosphere from entering the chamber 15 before the oxygen concentration in the chamber again falls below the predetermined amount. This is necessary to allow sufficient oxygen to be drawn into the chamber to be able to maintain the oxygen concentration in the chamber within an appropriate tolerance of the predetermined amount.

The opening to permit ambient atmosphere to enter the chamber may be the same opening 20 as the opening to permit chamber atmosphere to exit the chamber. However, it is preferred that a distinct opening is provided in the form of an openable and closeable inlet means to permit chamber atmosphere to enter the chamber.

Chamber atmosphere may be caused to enter the chamber through an opening by locating the opening near a source of low pressure inside the chamber, such that chamber 25 atmosphere is drawn into the chamber through the opening. The source of low pressure may be supplied by a fan. In an embodiment where the chamber is formed within a refrigerated container with a refrigeration fan inside the chamber, the refrigeration fan may be used as a source of low pressure.

Chamber atmosphere may be caused to enter the chamber through an opening by locating 30 the opening near a source of high pressure outside the chamber, such that chamber

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atmosphere is forced into the chamber through the opening. The source of high pressure may be supplied by a fan.

An opening for permitting chamber ambient atmosphere to exit the chamber may be provided wholly or partly by leakage paths out of the chamber. An opening may be added

- 5 to the chamber, such as by making one or more holes in the chamber. An opening may comprise existing leakage paths out of the chamber.

In the embodiment where the opening for permitting ambient atmosphere to exit the chamber is the same as, or one of, respectively, the opening or openings for permitting chamber atmosphere to enter the chamber, ambient atmosphere may be caused to enter the

- 10 chamber through the opening following turning off the source of high or low pressure (as the case may be), or removing it from the vicinity of the opening, so that when the pressure in the chamber is above ambient pressure, chamber atmosphere may be forced out of the chamber through the opening.

Following the influx of ambient atmosphere into the chamber, as stated, the pressure in the

- 15 chamber will exceed ambient pressure. The pressure differential will force chamber atmosphere to exit the chamber through the opening.

Sealing means may be applied to the chamber such that the chamber is sealed to the required extent ie such that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of

- 20 consumption of oxygen by the respiring produce.

Preferably, the method further comprises the step of removing carbon dioxide from the chamber atmosphere substantially at a predetermined rate, the predetermined rate having been selected such that the carbon dioxide concentration within the chamber atmosphere does not substantially exceed a predetermined amount.

- 25 The method may further provide for the inlet means to be open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

The method may further provide for the predetermined carbon dioxide removal rate to be calculated from a formula derived from a mathematical model of the proportions of the 30 chamber atmosphere subject to the requirement that the oxygen concentration within the

chamber be substantially maintained at a predetermined amount. The predetermined carbon dioxide removal rate is preferably calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$5 \quad a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

where  $a_{O_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

- 10     The method may further provide for at least part of the carbon dioxide removal to be effected by contacting a quantity of carbon dioxide absorbing material with the chamber atmosphere. The carbon dioxide absorbing material is preferably contained in at least one carbon dioxide transmissible container, such as for example a carbon dioxide transmissible bag. Preferably, the at least one carbon dioxide transmissible container is selected so that  
15     the rate of carbon dioxide transmission into the at least one carbon dioxide transmissible container is substantially equal to the predetermined carbon dioxide removal rate.

According to a further aspect of the present invention there is provided a method for converting a receptacle into an adjusted atmosphere chamber for containing respiring produce, the method comprising:

- 20     (a) forming a chamber in the receptacle that is sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, and which is open to the extent that when the chamber pressure is greater than ambient pressure following a chamber pressure increase as described in step (e) the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber falls below the predetermined amount described in step (e), to a level that will not prevent ambient atmosphere from entering into the chamber through the opening referred to in step (c);  
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- (b) optionally, installing sealing means so as to seal the chamber to the required extent;
- (c) installing an opening in the chamber to permit ambient atmosphere to enter the chamber;
- (d) optionally, installing an opening in the chamber to permit chamber atmosphere to exit the chamber;
- 5 (e) installing a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause ambient atmosphere to enter the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening in the chamber.

As above, the opening to permit ambient atmosphere to enter the chamber may be the same opening as the opening to permit chamber atmosphere to exit the chamber. However, it is preferred that a distinct opening is provided in the form of an openable and closeable inlet means to permit chamber atmosphere to enter the chamber.

The control means may cause chamber atmosphere to enter the chamber through an opening by locating the opening near a source of low pressure inside the chamber, or a 20 source of high pressure outside the chamber. In the case where an opening in the form of an inlet means is used, if the inlet means is always located near a source of high or low pressure, as the case may be, then the control means may cause chamber atmosphere to enter the chamber through the inlet means by opening the inlet means.

The method may further include the step of installing carbon dioxide removal means 25 adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate whereby the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains respiring produce. The method may further provide for the predetermined carbon dioxide removal rate to be calculated from a formula derived from a mathematical model 30 of the proportions of the chamber atmosphere subject to the requirement that the oxygen

concentration within the chamber be substantially maintained at a predetermined amount. The predetermined carbon dioxide removal rate is preferably calculated from a formula that produces a result substantially equal to the result produced by the aforementioned formula.

- 5 The method may further provide for the inlet means to be open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

According to a further aspect of the present invention there is provided a receptacle when converted into an adjusted atmosphere chamber in accordance with the methods for

- 10 converting a receptacle into an adjusted atmosphere chamber described herein.

According to a further aspect of the present invention there is provided apparatus for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of

- 15 consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following a chamber pressure increase as described below, the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber falls below the predetermined amount described below, to a level that will not

- 20 prevent ambient atmosphere from entering the chamber through an opening, the apparatus comprising a controller having an oxygen concentration sensor and control means

responsive to the oxygen concentration sensor, the control means being adapted to cause ambient atmosphere to enter the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined

- 25 amount so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening in the chamber.

Preferably, the apparatus includes openable and closeable inlet means to permit chamber atmosphere to enter the chamber. In this embodiment, the control means is adapted to

- 30 cause the inlet means to open to allow chamber atmosphere to enter the chamber. In this embodiment, a source of low pressure inside the chamber, or of high pressure outside the

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chamber, is provided. Such a source of high or low pressure may be part of the apparatus of the present invention, but is not essential, as the chamber may already have a readily useable source of pressure, such as a refrigeration fan inside the chamber.

Preferably the apparatus includes sealing means for sealing the chamber to the required

5 extent.

Preferably, the apparatus also includes carbon dioxide reduction means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate so that, in use, the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains respiration

10 produce.

The controller may be further adapted to cause the inlet means to remain open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

The apparatus may include inlet means that comprise one or more electromagnetically actuable valves having a solenoid so that said one or more valves may be opened from a closed position and closed from an open position by applying direct electric current to the solenoid, said one or more valves being held in either the open position or the closed position in the absence of the application of said direct electric current.

According to another aspect of the present invention, there is provided a method for 20 adjusting the atmosphere within a chamber containing respiration produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiration produce, the chamber having an opening to permit ambient atmosphere to enter the chamber, and an opening to permit chamber atmosphere to 25 exit the chamber, the method comprising:

- (a) monitoring the oxygen concentration within the chamber;
- (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing ambient atmosphere to enter the chamber through an opening so that the amount of oxygen in the chamber is or will be increased and 30 so that the pressure in the chamber is or will be increased above ambient pressure

such that chamber atmosphere is or will be expelled from the chamber through an opening; and

- (c) prior to steps (a) and (b), selecting an oxygen setpoint such that steps (a) and (b) cause the carbon dioxide concentration within the chamber atmosphere to not substantially exceed a predetermined amount,

the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following step (b) the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber again falls below the predetermined amount, to a level that will not prevent ambient atmosphere from being drawn into the chamber through the opening first referred to in step (b).

The opening for permitting chamber atmosphere to enter the chamber may be an openable and closeable inlet means as described above.

A chamber according to the present invention may be provided within any form of receptacle.

The invention is particularly applicable to chambers provided within a receptacle in the form of a shipping container. While it is convenient to hereinafter describe the invention in relation to that example application it is to be appreciated that the present invention is equally applicable to chambers provided by or within other forms of receptacle including cool stores, refrigerated vans, rail cars and other storage facilities.

The present invention accordingly provides in one embodiment a method for adjusting the atmosphere within a chamber. In this embodiment the method includes the step of predicting the carbon dioxide level in the chamber once the oxygen setpoint in the chamber has been determined. In this way the carbon dioxide level in the chamber may be adjusted.

The carbon dioxide level in the chamber can be adjusted by altering the setpoint of oxygen in the chamber. In one preferred embodiment, the oxygen level in the chamber can be set above the oxygen setpoint after flushing the chamber with a purging gas, following which the oxygen level degrades to the setpoint as a consequence of consumption of oxygen by the respiring produce, resulting in a proportional increase in the carbon dioxide level in the chamber.

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A significant advantage of the invention is that carbon dioxide levels in the chamber can be accurately predicted remotely and before transport of the produce, that is, the invention does not require active monitoring and control of the carbon dioxide levels while the produce is being transported. This obviates the need for complex carbon dioxide 5 monitoring and control apparatus, as prediction of the carbon dioxide level can be made before the produce is placed in the chamber.

The present invention provides in another embodiment a method for independently adjusting carbon dioxide levels in a chamber, the method including the step of placing a carbon dioxide absorbing material in the chamber whereby carbon dioxide is absorbed into 10 the material so that the level of carbon dioxide in the chamber reaches a desired equilibrium point. This aspect of the invention is predicated on the basis that if the rate of production of carbon dioxide in the chamber by the produce is estimated, a predetermined equilibrium can be achieved by adding the required amount of carbon dioxide absorbing material to the chamber. Hence independent adjustment of the carbon dioxide level in the 15 chamber can be achieved.

The present invention provides in another embodiment a method for adjusting the atmosphere within a chamber containing respiring produce, the method comprising:

- (a) flushing the chamber with a purging gas containing little or no oxygen;
- (b) adjusting the oxygen level in the chamber to a level above a desired oxygen 20 setpoint;
- (c) permitting the oxygen level in the chamber to degrade to about the oxygen setpoint as a consequence of oxygen consumed by the produce being converted to carbon dioxide;
- (d) removing chamber atmosphere from the chamber; and
- 25 (e) repeating steps (b), (c) and (d) as required if the oxygen level falls below the oxygen setpoint, to maintain the oxygen level in the region of the oxygen setpoint.

The present invention provides in another embodiment a method for adjusting the level of carbon dioxide in a chamber containing respiring produce, the method comprising the step of placing a carbon dioxide absorbing material in the chamber so as to absorb the 30 difference between a predicted level of carbon dioxide in the chamber based on the rate of

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consumption of oxygen by the produce and a desired carbon dioxide level so that the carbon dioxide concentration in the chamber does not substantially exceed said desired level.

Atmosphere adjustment apparatus provided by the present invention may include sealing 5 means, inlet means, outlet means and a controller.

Sealing means according to the present invention is provided to seal the chamber to the required extent. Where inlet means and/or outlet means are used in conjunction with an opening in the chamber and the chamber must be sealed to the extent that, when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage 10 of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, sealing means may be used or not, as necessary.

It may be useful to conduct tests on potential containers to determine the leakage rate in order to determine whether they may be immediately employed in accordance with the present invention or whether they should be rejected or repaired. The presently preferred 15 testing method for use in relation to (empty) shipping containers is to first seal the container and then pump air into the container at a regulated flow rate through an appropriate fitting in an air vent in the container. At another air vent, there is provided a manometer tapping to measure the pressure inside the container.

The preferred testing method employs the principle that, at a constant pressure within the 20 container, the flow rate into the container must equal the flow rate out of the container (through the various leakage paths). Accordingly, the flow rate of air being pumped into the container is adjusted until the pressure remains constant at a particular target pressure. It will be appreciated by those skilled in the art that the appropriate degree of air tightness 25 for a container depends upon whether the produce to be stored has a high or low respiration rate.

The sealing means may act as a moisture barrier. The sealing means may act as a barrier to the passage of gas into or out of the chamber. The chamber may comprise substantially the entire internal volume of the receptacle or a reduced volume within the chamber.

The point of entry to a chamber is liable to leak. The point of entry to a chamber is 30 typically in the form of one or more doors. In particular, it has been found that for

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shipping containers, the seals of the doors of the container are generally the source of most leakage. Consequently, the sealing means provided in accordance with the present invention may include door sealing means.

- The sealing means provided by the present invention may also include a curtain. The
- 5 curtain may comprise a substantially fluid impervious sheet. The curtain may substantially seal an open end of a receptacle to form the chamber. The curtain may seal the chamber from leakage paths in the receptacle that are outside the chamber. In particular, the curtain may seal the chamber from any leakage paths in the door seals of the receptacle by being interposed between the chamber and receptacle door.

- 10 A curtain may be attached to the internal and/or external walls of the receptacle by any suitable means. Adhesive, including tape or glue, may be used.

In a preferred embodiment of the present invention, there is provided a curtain for use in conjunction with a receptacle made from a magnetic material, such as a steel shipping container. The curtain is provided with numerous permanent magnets adjacent its periphery for attaching the curtain to the receptacle. In a particularly preferred embodiment for use in conjunction with a steel shipping container, the curtain is installed in the container when the doors are open by attaching the magnets to the external walls of the container. Once the curtain is suitably placed, the doors of the container are closed to thereby substantially seal the curtain against the container.

- 15 20 A curtain according to one aspect of the present invention is preferably located close to the door of the receptacle in order to maximise the volume of the chamber. The curtain is preferably approximately coplanar with the receptacle door when the curtain is in a substantially un-deformed state where there is equal pressure on either side of the curtain.

Refrigerated shipping containers (sometimes known as reefer containers) are generally of a  
25 standard style of construction. Such containers typically have a false floor. The produce sits on the false floor which is spaced from the outer wall of the container to facilitate air flow within the container. The false floor typically terminates a short distance from the end of the container to facilitate air flow at the ends of the load stored within the container.

- 30 The curtain is preferably located within the space between the container door and the beginning of the false floor.

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In this arrangement the chamber is accordingly bounded by the container walls and the curtain with the space between the curtain and the container door being outside the chamber.

The sealing means provided in accordance with the present invention may also include a  
5 cover for any ventilation port in the shipping container or other receptacle. The cover may comprise a sheet of flexible material such as an expanded rubber sheet. The sheet may be initially oversized and subsequently trimmed on site to form a cover which matches the profile of the ventilation port whereby to seal it. The cover may be installed over the ventilation port by any means. Preferably the cover is adhered to the port and/or the wall  
10 immediately surrounding the port with tape and/or glue. Where a port comprises a number of apertures, one or more covers may be used to seal the port.

The cover is substantially impermeable. The cover may include one or more layers which are not substantially impermeable. In this case, the cover may include a substantially impermeable layer such as an adhesive sheet to adhere the cover to the port and/or the wall  
15 immediately surrounding the port. The substantially impermeable adhesive sheet is preferably applied so as to substantially cover the permeable material. In this way the cover may be rendered substantially impermeable.

Inlet and outlet means provided in accordance with the present invention may be operable to facilitate respectively the inflow of ambient atmosphere into the chamber and the  
20 outflow of chamber atmosphere from the chamber.

Inlet and outlet means may each comprise one or more valves operable to provide in an open position communication between the chamber atmosphere within the chamber and the ambient atmosphere surrounding the chamber. Each valve may be operable in a closed position to substantially restrict such communication.

25 Inlet means and outlet means each may be located in any boundary of the chamber.

In a typical arrangement, the outlet means is located adjacent to a fan provided in the chamber for circulating air within the chamber. Preferably, the outlet means is mounted in a ventilation port near the fan. In the case of a standard refrigerated shipping container having a fan at one end of the container, the outlet means is preferably mounted in the  
30 ventilation port that is typically located adjacent to the fan.

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- If both inlet means and outlet means are used, the inlet means is preferably spaced from the outlet means. Preferably the arrangement of the inlet means and outlet means is such as to facilitate the free flow of atmosphere between the interior and exterior of the chamber. Most preferably the inlet and outlet means are positioned relative to one another so as to
- 5 facilitate cross-flow ventilation when each is in the open position. Most preferably the inlet and outlet means are located at either end of the chamber.

Inlet means and/or outlet means may be mounted in a curtain according to the present invention. In this case, installation of the curtain also includes installation of the inlet means and/or outlet means. The inlet means and/or the outlet means may each include a

10 plurality of valves. Such valves may be spaced from one another in locations which facilitate a desired air flow.

The valves comprising the inlet means and/or outlet means may be operable in response to a signal from the controller. Each valve may be connected to the controller by wire or other means for conveying a signal from the controller to the valve.

- 15 Each valve provided according to the present invention may be magnetically operable between an open position and a closed position. A solenoid is preferably provided to generate a magnetic field in response to the application of a direct current whereby to urge the valve toward an open or a closed position dependent upon current direction.

Valves comprising the inlet and outlet means according to the present invention are

20 preferably electromagnetically actuatable valves having a solenoid so that they may be opened from a closed position and closed from an open position by applying direct electric current to the solenoid, said one or more valves being held in either the open position or the closed position in the absence of the application of said direct electric current.

- Valves according to the present invention preferably may be both opened from a closed
- 25 position and closed from an open position by applying a pulse of direct electric current to the solenoid. Preferably, the valves are adapted to be held in the closed position or the open position in the absence of an electric current in the solenoid by magnetic forces.

According to an aspect of the present invention, a valve comprising the inlet or outlet means according to the present invention comprises a bore, a member moveable within the

30 bore, at least one sealing surface associated with the member, at least one aperture through

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which fluid may pass to pass through the valve, a solenoid adapted to generate a magnetic field in the bore in response to the application of a direct electric current, the member being adapted to move with respect to the bore in response to said magnetic field between a valve open position wherein fluid passes through said at least one aperture and a valve

- 5 closed position wherein said at least one sealing surface prevents fluid passing through each said at least one aperture. Preferably, the member is a slidable within the bore. Preferably, the slidable member carries at least one cover adapted to cover each said at least one aperture to prevent fluid passing through said at least one aperture.

According to an aspect of the present invention, a valve comprising the inlet or outlet  
10 means according to the present invention comprises at least one aperture through which fluid may pass to pass through the valve, a solenoid to generate a magnetic field in response to the application of a direct electric current and a flap which is adapted to move in response to said magnetic field between a valve open position wherein fluid may pass through the valve through said at least one aperture and a valve closed position wherein the  
15 flap prevents fluid passing through the valve through any said at least one aperture.

Preferably, the solenoid is located between the flap and a member carried by the flap, the member and the flap each having a permanent magnet so arranged that when a direct electric current is passed through the valve in one direction the solenoid attracts the magnet on the member and repulses the magnet on the flap in order to move the flap to a valve  
20 open position and when a direct electric current is passed through the solenoid in a direction opposite to said one direction the solenoid repulses the magnet on the member and attracts the magnet on the flap in order to move the flap to a valve closed position.

Preferably an armature is provided in the solenoid and the flap may held in the valve open position in the absence of an electric current in the solenoid by the magnetic attraction  
25 between the armature and the magnet on the member, and the flap may held in the valve closed position in the absence of an electric current in the solenoid by the magnetic attraction between the armature and the magnet on the flap.

In one preferred form a valve comprises a magnetic member moveable along a bore in response to the field generated by passing a direct current through a solenoid surrounding  
30 the bore. The member may be captured within the bore and moveable between positions which open and close the valve.

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The magnetic member may take any suitable shape. The magnetic member may be a ball. It may be a right circular cylinder. It may be a prismatic member having a cross-section of any suitable shape. Other magnetic member shapes are envisaged within the scope of the invention.

- 5 In one embodiment of this principle, the magnetic member is in the form of a ball. The valve contains a hole through which fluid must pass to pass through the valve. The ball seals the valve by sealingly abutting the edge of the hole. Preferably the hole is a hole in a plate in the valve. The diameter of the ball is greater than the diameter of the hole.
- 10 In another embodiment of this principle, the magnetic member is in the form of a member which is slidable with respect to the valve body. Preferably, the slidable member is a cylindrical rod. The slidable member carries a cover with a sealing surface. Preferably the cover is a panel with an annular sealing surface. The fluid path through the valve when the valve is open includes one or more holes. Preferably the holes are holes in a plate in the valve. The cover seals the valve by sealingly abutting the surface around the holes. Where
- 15 the cover is a panel with an annular sealing surface, the valve is closed by the annular sealing surface sealingly abutting the surface around the holes. The outer diameter of the annular sealing surface is greater than the diameter of a circle surrounding the hole or holes. Preferably, the inner diameter of the annular sealing surface is also greater than the diameter of a circle surrounding the hole or holes.
- 20 In another preferred form the valve comprises a flap moveable under the application of a magnetic field between open and closed positions. The flap may carry a magnet. The flap may be hingedly mounted with respect to a base. The base may carry a solenoid or coil for generating a magnetic field to open or close the flap and hence the valve in response to a signal from the controller.
- 25 A valve according to the present invention may be provided with a casing. Any such casing must allow sufficient fluid flow through the valve when the valve is open. The casing may only partially encase the valve. The casing may be apertured. In particular, a casing may contain holes. Such holes may be any suitable shape. They may be circular. They may be slots. Other aperture shapes are envisaged within the scope of the invention.
- 30 Where a valve according to the present invention has an apertured casing, preferably the apertures are located so that any relative movement between the valve and the contents of

the chamber or another part of the chamber will not prevent fluid flowing through the valve when the valve is open. In particular, where a valve with an apertured casing is mounted on a curtain according to the present invention, preferably the apertures are located so that the apertures will not be obstructed so as to ensure that the flow of fluid is  
5 not restricted to any significant extent.

For example, where a valve with a casing is mounted in a curtain which is approximately coplanar with the receptacle door when the curtain is in a substantially un-deformed state, preferably the casing includes apertures on the side of the valve rather than, or in addition to, the front or back face of the valve so that if the valve moves so that the front or back  
10 face abuts the door or another object with its front or back face, the apertures will not thereby be obstructed.

- Where there is a curtain according to the present invention that is flexible, the differential between the pressures of the atmospheres on each side of the curtain may vary at different points on the curtain. This variation can cause the curtain to move somewhat erratically.
- 15 To facilitate equalisation of the pressure differential over the surface of the curtain, the curtain may be provided with inlet means or outlet means in the form of valves, or openings, that are spaced apart. In a typical arrangement a curtain may carry inlet means or outlet means in the form of a pair of valves. One valve may be located in the upper portion and the other in the lower portion of the curtain.
- 20 A controller according to the present invention includes sensor means and control means. The sensor means is operable for sensing the concentration of oxygen. The sensor means may also sense other variables within the chamber, for example, humidity. Preferably the sensor means includes an oxygen concentration measurement device which provides an output in the form of an electrical signal containing information about the oxygen  
25 concentration level within the chamber. Such an electrical signal may be a direct current signal having voltage proportional to oxygen concentration or the signal may digitally encode the oxygen concentration level or a number that is proportional, or otherwise in known relation to, the oxygen concentration. Other forms of output are also envisaged within the scope of the present invention.
- 30 A controller according to the present invention may include means to receive and respond to the sensor means output. Such response may include activating one or more valves or

other devices subject to the control of the controller. The controller may be operatively connected to the valves by direct wire connection or other means for facilitating the activation of one or more valves by the controller. The controller may receive signals from the sensor means continuously or may sample the signals discontinuously. Where the 5 signals are sampled discontinuously, the sampling intervals may be equal or unequal. The sampling interval may be made to vary according to the output of the sensor means or may be fixed.

Apparatus according to the present invention preferably includes a passive carbon dioxide concentration reduction means. Preferably the reduction means comprises a predetermined 10 quantity of a suitable substance for extracting carbon dioxide from the atmosphere, such as hydrated lime, held in carbon dioxide transmissible bags. Such reduction means is already known in the art. The quantity of suitable substance to be placed within the chamber may be calculated from a knowledge of the total amount of carbon dioxide above the maximum tolerable amount of carbon dioxide within the chamber that is likely to enter the chamber 15 and/or be produced through respiration of produce. This maximum amount may be estimated from a knowledge of the temperature at which the chamber is to be held, the time throughout which the atmosphere is to be adjusted, the amount of produce to be stored within the chamber and the respiration rate of the produce to be stored within the chamber. The means of estimation is further discussed below.

20 Apparatus according to the present invention may include a humidifier preferably a passive humidifier. A passive humidifier may comprise a tray for catching water dripping from the evaporation coil of a refrigeration unit within the chamber. The humidifier may include wick means for conveying the water to a point near the fan for circulating air within the chamber so that the moisture may be blown into the chamber to increase the humidity 25 thereof.

After produce has been loaded into a chamber fitted with atmosphere adjustment apparatus according to the present invention the chamber may be flushed with a gas having a low oxygen concentration or containing no oxygen. Nitrogen may be used as the gas. Such a gas flushing step may be effected to lower the initial oxygen concentration within the 30 chamber to below a predetermined maximum oxygen concentration. If the oxygen content is thereby lowered below a predetermined minimum oxygen concentration, the controller

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may operate to cause the oxygen concentration within the chamber to be increased. If such a gas flushing step were not carried out, it would take considerable time for the oxygen concentration within the chamber to be lowered as a result of consumption of oxygen by produce during respiration.

- 5 The gas flushing step may be effected to lower the initial oxygen concentration within the chamber to within a few percent of the oxygen setpoint. If the oxygen content is lowered to the oxygen setpoint by the action of respiring produce, it has been observed that there is a corresponding proportional increase in the carbon dioxide level in the chamber.

Prediction of the desired characteristics of the absorbing unit to achieve the desired 10 concentration of carbon dioxide corresponding to a particular oxygen pre-set level in the chamber is also based on, amongst other things, the weight of the cargo, the temperature in the chamber, the time during which the cargo will be in transit, and the respiration quotient of the produce.

In use, when the oxygen concentration within the chamber falls below a first 15 predetermined minimum value, the controller causes the inlet means and/or the outlet means to open for a first predetermined length or lengths of time (as the case may be) so as to allow air surrounding the chamber to enter the chamber and/or atmosphere from within the chamber to exit the chamber. The influx of air into the chamber will thereby increase the oxygen concentration within the chamber.

- 20 If both inlet means and outlet means are used, the inlet means and the outlet means may be opened simultaneously. They may be closed simultaneously. They may be opened at different times. They may be closed at different times. The option-of staggering the opening (or closing) of the inlet means with respect to the opening (or closing) of the outlet means, as compared to simply opening and closing the inlet means and outlet means 25 simultaneously, can allow additional control over the rate of variation of the concentrations of gases within the chamber.

Where inlet means and/or outlet means are used together with a non-closeable opening in the chamber, an increase or decrease in chamber pressure may be used to increase the oxygen concentration within the chamber, as described above, in order to maintain the 30 oxygen level substantially at the oxygen setpoint.

- If, after the inlet means and/or outlet means have closed, the oxygen concentration as measured by the sensor means has not increased to at least a second predetermined minimum value, the controller may cause the inlet means and/or the outlet means to switch to an open state for a second predetermined length or lengths of time (as the case may be)
- 5 so as to allow further air surrounding the chamber to enter the chamber and/or atmosphere from within the chamber to exit the chamber. The second predetermined minimum value of the oxygen concentration may be equal or unequal to the first predetermined minimum value of the oxygen concentration.

This process may be repeated until the oxygen concentration has increased to an acceptable

10 level.

If, after the inlet means and/or outlet means have closed, the oxygen concentration within the chamber as measured by the sensor means has not increased to at least the second predetermined minimum value, the controller may determine not to cause the inlet means and/or outlet means to switch to an open state for any second or subsequent predetermined

15 lengths of time in order to allow time for the oxygen concentration as measured by the sensor means to increase due to mixing of the atmosphere within the chamber.

In a given cycle of increasing the oxygen concentration within the chamber, where the inlet and/or outlet means are opened for a second or subsequent predetermined length or lengths of time, the various predetermined lengths of time may be equal or unequal. Preferably,

20 each subsequent opening of the inlet and/or outlet means within a single cycle of increasing the oxygen concentration within the chamber is longer than the previous. For example, preferably the second predetermined length or lengths of time are longer than the first predetermined length or lengths of time, the third is or are longer than the second and so on.

25 In a given cycle of increasing the oxygen concentration within the chamber, where the inlet and/or outlet means are opened for a second or subsequent predetermined length or lengths of time, the various predetermined lengths of time may be adjusted by the controller in response to the measurements of the sensor means.

In an embodiment of the present invention, where both inlet means and outlet means are

30 provided, the inlet means and outlet means are each opened and closed together, that is, they are each opened and closed at the same times.

Preferably, the length of time for which the inlet means and/or outlet means are open is approximately proportional to the difference between the measured oxygen concentration and the oxygen setpoint. By "approximately proportional", we mean that the length of time the inlet means or outlet means is open should be small if the difference is small and 5 large if the difference is large. A true proportionality in the sense of a linear relationship between oxygen concentration difference and length of time of opening of the inlet means or outlet means, is not required. (This situation only arises when the measured oxygen concentration is less than the oxygen setpoint because when the measured oxygen concentration exceeds the oxygen setpoint, the inlet means and/or outlet means would 10 remain closed.)

In a preferred embodiment of the present invention, where the chamber according to the present invention is formed within a refrigeratable shipping container, the following logic is used to control the oxygen concentration within the chamber:

1. Measurement of chamber oxygen concentration takes place every 8 minutes.
- 15 2. If the difference between the measured oxygen concentration and the oxygen setpoint is more than 0.9%, then the inlet means is opened to allow ambient air to enter the chamber to thereby increase the oxygen concentration within the chamber. (For the avoidance of doubt, the reference to "0.9%" is in units of chamber oxygen concentration and does not represent a proportion of the oxygen setpoint.) The inlet means and/or outlet means is/are closed after the measured oxygen concentration 20 has exceeded the oxygen setpoint.
3. If the measured oxygen concentration is in the range 0 to 0.9% less than the oxygen setpoint, then the inlet means and/or outlet means is/are opened to allow ambient air to enter the chamber to thereby increase the oxygen concentration within the chamber. The inlet means and/or outlet means is/are closed after a time that is dependent on the oxygen concentration as measured prior to opening the inlet means, as follows:

| Setpoint - oxygen concentration (%) | Time (minutes) |
|-------------------------------------|----------------|
| above 0 to 0.09                     | 1.5            |

|                    |     |
|--------------------|-----|
| above 0.09 to 0.18 | 2   |
| above 0.18 to 0.27 | 2.5 |
| above 0.27 to 0.36 | 3   |
| above 0.36 to 0.45 | 3.5 |
| above 0.45 to 0.54 | 4   |
| above 0.54 to 0.63 | 4.5 |
| above 0.63 to 0.72 | 5   |
| above 0.72 to 0.81 | 5.5 |
| above 0.81 to 0.9  | 6   |

In one preferred embodiment of the present invention methods according to the invention include the determination of a respiration quotient of a particular produce to be placed in the chamber, that is, the amount of oxygen which converts to carbon dioxide by respiration of that produce. The respiration quotient is produce dependent, although in general terms

- 5 it has been observed there is a directly proportional relationship between the amount of oxygen consumed by the produce which converts to carbon dioxide. Hence, generation of carbon dioxide within the chamber is dependent on the oxygen level within the chamber. In a sealed chamber whose volume has respiration produce and air, the produce consumes oxygen thereby reducing the oxygen level in the chamber. As a consequence of
- 10 consumption of the available oxygen, the produce gives off a proportional amount of carbon dioxide to the oxygen consumed.

- By way of example, it is well known that ambient air contains approximately 21% oxygen by volume. If an oxygen level of 6% in a chamber containing produce and ambient air is required, it can be predicted in accordance with the present invention that the composition
- 15 of the atmosphere in the chamber will over time contain approximately 15% carbon dioxide (from an approximately zero base) as a consequence of the consumption of oxygen by the produce. Similarly, if a level of 3% oxygen in the chamber is required, it can be predicted that the composition of the atmosphere in the chamber will over time contain approximately 18% carbon dioxide (from an approximately zero base) as a consequence of
  - 20 the consumption of oxygen by the produce.

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In accordance with the method for independent adjustment of the carbon dioxide level, the carbon dioxide absorbing material may be provided so as to absorb the difference between the predicted level of carbon dioxide to be generated and a desired equilibrium point, say 10%.

- 5 A calculation may hence in one embodiment be performed based on the known absorption characteristics of the carbon dioxide absorbing material and the desired degree of absorption of carbon dioxide, to arrive at an estimate of the amount of material required to absorb the difference in the predicted level of carbon dioxide and the desired carbon dioxide equilibrium point.

In general, a carbon dioxide level in the chamber in the range of about 0 to 15% by volume 10 of the chamber is desired. The advantage of having at least a proportion of carbon dioxide in the composition of the chamber atmosphere is that it assists in the produce retaining its colour, inhibits the growth of mould and rots, and assists in retardation of produce ripening. Too much carbon dioxide could however cause deterioration in produce quality.

In accordance with one preferred embodiment of the present invention, if for example an 15 oxygen setpoint of 5% by volume in the chamber is required, the oxygen level is initially reduced to within about 3% above the setpoint, following which the oxygen level degrades to 5% and the carbon dioxide level increases to approximately 3% (from an approximately zero base). The oxygen level can be held at the oxygen setpoint by causing air to enter the chamber if the level falls below the setpoint.

- 20 Naturally however, the produce will continue to consume oxygen and hence carbon dioxide will continue to be produced. Independent adjustment of the carbon dioxide level can be achieved by placing a carbon dioxide absorbing material, such as one or more containers of hydrated lime of predetermined transmissibility to carbon dioxide in the chamber, so as to absorb the difference between the predicted carbon dioxide in the 25 chamber (based on the predicted rate of consumption of oxygen by the produce) and the desired level.

The present invention provides in one particularly preferred embodiment a method for adjusting the atmosphere within a chamber for containing respiring produce, the method including the steps of predicting the carbon dioxide level in the chamber once the oxygen 30 setpoint in the chamber has been determined, and independently adjusting the carbon dioxide level in the chamber by determining the difference between the predicted level of

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carbon dioxide in the chamber and the desired carbon dioxide equilibrium point and adding one or more containers of hydrated lime of predetermined transmissibility to carbon dioxide to the chamber whereby carbon dioxide is absorbed into the bags so that it reaches the desired equilibrium point, whereby to adjust the level of carbon dioxide in the chamber.

- 5 In describing the operation of the present invention, it is convenient to first describe an embodiment in which the carbon dioxide level in the chamber is not modified.

Following sealing of the chamber, respiration of the produce will cause the oxygen concentration in the chamber to decrease and the carbon dioxide concentration to increase. If the initial chamber atmosphere is ambient atmosphere, then the initial carbon dioxide

- 10 concentration is zero to a good approximation. The molar amount of carbon dioxide produced during respiration is, by definition, the product of the amount of oxygen consumed and the respiration quotient.

- Inlet means and/or outlet means of the present invention will remain closed until the sensor detects that the oxygen concentration within the chamber has fallen below a predetermined  
15 amount (which is typically set within a particular margin or tolerance of the oxygen setpoint). Continued respiration of the produce causes, or would cause, the oxygen concentration within the chamber to go below the set point (or below a level within an appropriate margin or tolerance in the set point). Apparatus of the present invention causes the inlet means and/or the outlet means to open for a predetermined length of time to  
20 increase the oxygen concentration within the chamber.

The cycle of opening the inlet means and/or outlet means when the oxygen concentration has fallen below a predetermined amount continues in order to maintain the oxygen concentration in the chamber substantially at the oxygen setpoint.

- Although inflow and/or outflow to and/or from the chamber may occur at discrete time  
25 intervals as described, it is useful to model the process as a continuous process by assuming that there is a constant rate of inflow of air, a constant rate of outflow of chamber atmosphere and a constant rate of respiration within the chamber. The notional continuous flow rates may be considered as a form of average of the actual, partially or wholly discrete, flow rates. The invention is not to be construed as being in any way limited to a

theoretical mode of action, model or description. However, as will be seen, such a model is useful in adjusting the carbon dioxide concentration within the chamber.

In the absence of controlling the carbon dioxide concentration in the chamber, the carbon dioxide concentration in the chamber will reach an equilibrium value. At equilibrium, the

5 rate of production of carbon dioxide in the chamber through respiration balances the rate of carbon dioxide exiting the chamber through outlet means or an opening in the chamber. In calculating the equilibrium carbon dioxide concentration, a model with the following assumptions is used:

1. The chamber atmosphere exiting the chamber through outlet means or an opening  
10 in the chamber is perfectly mixed (ie it is assumed that the proportions of constituent gases of the atmosphere exiting the chamber is equal to the proportions of constituent gases within the chamber).
2. The composition of the air entering the chamber through inlet means or an opening in the chamber consists of 21% oxygen and 79% nitrogen.
- 15 3. The rate of inflow of nitrogen is equal to the rate of outflow of nitrogen.

Calculations according to the above model are presented in the Appendix to this specification.

Using a model having the above assumptions, the carbon dioxide concentration in the chamber atmosphere at equilibrium in the absence of carbon dioxide modification within

20 the chamber  $p_{CO_2}^*$  is approximately  $RQ \cdot (0.21 - p_{O_2})$  where  $p_{O_2}$  is the oxygen setpoint, and  $RQ$  is the respiration quotient. (The correct expression using the model is

$$p_{CO_2}^* = \frac{RQ \cdot (0.21 - p_{O_2})}{0.79 + 0.21 \cdot RQ}, \text{ see equation (9) in the Appendix.}$$

For example, when the oxygen concentration by volume is reduced from ambient level (ie 21%) to a setpoint of, say, 6%, then the carbon dioxide concentration will approximately 25 be 15% from an approximately zero base, assuming a respiration quotient of unity.

When an initial gas flushing step as described is used, the carbon dioxide concentration will still reach the same equilibrium concentration  $p_{CO_2}^*$  as when no initial gas flushing

step is used. Consequently, the present invention includes a method for estimating the

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equilibrium carbon dioxide concentration based on only the oxygen set point and the respiration quotient.

Using the previous numerical example, if an oxygen set point of 6% is adopted, then (using a respiration quotient of unity), the carbon dioxide concentration in the chamber will

- 5 ultimately reach an equilibrium concentration of 15%, whether the initial chamber atmosphere is ambient and whether or not an initial inert gas flushing step as described is used.

According to the present invention the equilibrium carbon dioxide concentration in the chamber may be modified without any monitoring of the carbon dioxide level in the  
10 chamber. From equation (10) in the Appendix, the rate of carbon dioxide absorption can be calculated. For example, if an oxygen set point of 6% is used, then as previously stated, in the absence of carbon dioxide absorption, the equilibrium carbon dioxide concentration will be approximately 15%. If it is desired to have an equilibrium carbon dioxide concentration of 10%, then from equation (10) or (12), the rate of carbon dioxide  
15 absorption required will be approximately  $0.39r_{O_2}$ , ie 0.39 times the rate of respiration rate of the produce (assuming a respiration quotient of unity).

Once the required carbon dioxide absorption rate  $a_{CO_2}$  is known, this information may be used to calculate the carbon dioxide transmissibility properties of a container of carbon dioxide absorbing material, such as bags of lime.

- 20 Commercial films of known carbon dioxide transmissibility are typically specified with reference to a transmission coefficient  $k_f$  which represents the flow rate of carbon dioxide through the film (typically in litres per minute), per percent of carbon dioxide in the atmosphere, per unit area of film (typically in square metres). Thus, if the required rate of carbon dioxide absorption is expressed in suitable flow units (designated  $a_{CO_2}$ ) (eg units  
25 of flow rate such as litres per minute), then the product of the area of the film and the transmission coefficient will equal the quotient of the carbon dioxide absorption rate and the carbon dioxide equilibrium concentration. That is,  $k_f A = \frac{a_{CO_2}}{PCO_2}$ . Suitable carbon dioxide transmissible containers may then be selected based on the product  $k_f A$ .

According to the method of the present invention, the predicted equilibrium carbon dioxide concentration in the chamber can be set in advance so that it will reach the desired level by using a carbon dioxide concentration reduction means (such as carbon dioxide transmissible containers filled with carbon dioxide absorbing material).

- 5 The amount of carbon dioxide absorbing material placed in the carbon dioxide transmissible containers should be sufficient to be capable of absorbing all the carbon dioxide that enters the carbon dioxide transmissible containers and therefore needs to be a sufficient amount to last the estimated time of storage of produce within the chamber.

It will be readily appreciated by those skilled in the art that other suitable forms of modelling the proportions of chamber atmosphere may be used, and such models are considered to fall within the scope of the present invention. For example, a model may take into consideration a factor for leakage from the container. A model may be based on discrete time intervals rather than using the continuous flow approximation.

#### Brief Description of the drawings

- 15 Embodiments of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic side view of a standard refrigerated container fitted with atmosphere adjustment apparatus according to a preferred embodiment of the present invention;

- 20 Figure 2 is a side elevation of a valve for use at the machinery end of a refrigerated container in accordance with an embodiment of the present invention;

Figure 3 is a front elevation of the valve according to Figure 2;

Figure 4 is a rear elevation of the valve according to Figure 2;

- 25 Figure 5 is a front elevation of a valve for use in a curtain according to the preferred embodiment of Figure 1;

Figure 6 is a rear elevation of the valve according to Figure 4;

Figure 7 is a side elevation of the valve according to Figures 4 and 5.

Figures 8 and 9 are side elevations of a valve for use in a curtain according to the preferred embodiment of Figure 1;

Figure 10 is a front elevation of a plate within the valve according to Figures 8 and 9; and  
Figure 11 is a schematic diagram of the mathematical model described in the Appendix.

Figure 1 shows a receptacle in the form of refrigerated container 10 which includes  
5 refrigeration unit 12 and doors 14. Refrigeration unit 12 includes a fan (not shown).

In the embodiment illustrated, sealing means is provided and includes a curtain 16. The curtain preferably comprises an impervious sheet and is attached to the external walls of container 10 with tape or magnets (not shown) to form chamber 11. The embodiment includes atmosphere modification means 9 comprising a quantity of hydrated lime held in  
10 carbon dioxide transmissible bags located within chamber 11.

Sealing means (not shown) in the form of a cover for ventilation port 18 is located at the machinery end of the container 10. The cover comprises an impervious plastic sheet adhered with tape to the wall of the container 10. The cover is adapted to cover, and hence seal, ventilation port 18. The cover is fitted with outlet means in the form of a valve 20.

15 Valve 20 is located on the high pressure side of the fan so that when valve 20 is open, chamber atmosphere is or will be forced out of the chamber.

An opening in the form of leakage paths or suitably sized holes (not shown) in the receptacle or in the sealing means is used to allow influx of ambient atmosphere. The leakage paths or holes are such that chamber 11 is sealed to the extent that when the  
20 pressure within chamber 11 is substantially equal to ambient pressure the rate of leakage of oxygen into chamber 11 is less than the rate of consumption of oxygen by respiring produce in chamber 11, and the chamber is open to the extent that when the chamber pressure is less than ambient pressure following a pressure reduction in chamber 11 (to be described below), the rate of entry of oxygen into chamber 11 is greater than the rate of consumption of oxygen by the respiring produce.

Controller 8 includes sensor means (not shown) in the form of an oxygen concentration measurement device. The sensor means preferably takes measurements at equally spaced intervals which may be adjusted depending upon the rate of respiration of produce in chamber 11.

Following detection that the oxygen concentration has fallen below the predetermined value due to consumption of oxygen by the respiring produce in chamber 11, controller 8 sends a signal to open valve 20. When valve 20 is open, chamber atmosphere is or will be forced out of the chamber through the open valve by the fan. This outflow of chamber

- 5 atmosphere causes the pressure in chamber 11 to be reduced below ambient pressure. The reduced chamber pressure causes ambient atmosphere to be drawn into chamber 11 through the leakage paths or holes to increase the amount of oxygen in chamber 11.

In this embodiment, chamber 11 is open to the extent that when the chamber pressure is less than ambient pressure following the pressure reduction described above, the rate of 10 leakage of oxygen into chamber 11 is greater than the rate of consumption of oxygen by the respiring produce. Chamber 11 must be open to this extent in order for sufficient oxygen to be drawn into chamber 11 to be able to maintain the oxygen concentration in the chamber within appropriate tolerances of the predetermined value.

In an alternative embodiment, the cover is fitted with inlet means in the form of a valve 20. 15 Valve 20 is located on the low pressure side of the fan so that when valve 20 is open, ambient atmosphere is or will be drawn into chamber 11. In this embodiment, following detection that the oxygen concentration has fallen below the predetermined value, controller 8 sends a signal to open valve 20. When valve 20 is open, ambient atmosphere is or will be drawn into chamber 11 through the open valve to increase the amount of 20 oxygen in chamber 11. This influx of ambient atmosphere causes the pressure in chamber 11 to increase above ambient pressure. Chamber atmosphere is thus forced out of chamber 11 through leakage paths or holes.

In this embodiment, chamber 11 is open to the extent that when the chamber pressure is greater than ambient pressure following the pressure increase described above, the rate of 25 leakage of chamber atmosphere out of chamber 11 is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber again falls below the predetermined amount, to a level that will not prevent ambient atmosphere from being drawn into the chamber through valve 20. Chamber 11 must be open to this extent in order for sufficient chamber atmosphere to exit the chamber so that the pressure in the chamber 30 reduces to a level that will not prevent ambient atmosphere from being drawn into the

chamber to increase the oxygen level when valve 20 must next be opened following detection that the oxygen level has fallen below the predetermined value.

As shown in Figure 2, valve 20 includes a casing 22 having a circular cylindrical outer surface 23 and an apertured end piece 24. End piece 24 includes apertures 25 as shown in

- 5 Figure 3. End piece 24 contains a central circular cylindrical boss 26 as shown in Figure 2 and in dotted outline in Figure 3. Boss 26 contains a magnet 28.

Valve 20 includes spacer rings 30 and 32.

Valve 20 includes a reel 38 provided with flanges 40 and 42 and a central circular bore 44.

- 10 Wire (not shown) is coiled around the reel 38 between the flanges 40 and 42 to create a solenoid. In the preferred embodiment illustrated, a spherical ball 60 is located in bore 44 of reel 38. Ball 60 may be substituted with a right circular cylindrical plug or a member of any suitable shape.

In the preferred embodiment illustrated, the ball 60 is magnetic ie is attracted by a magnet.

- 15 The diameter of ball 60 is greater than the length of reel 38 as measured from the outer surface of flange 40 to the outer surface of flange 42 along a line parallel to the axis of bore 44. The diameter of bore 44 exceeds the diameter of ball 60.

A sealing plate 34 is provided having a central circular hole 36 which is substantially concentric with the bore 44. The diameter of the hole 36 is less than the diameter of the ball 60.

- 20 An end cap 50 is provided having 6 circular apertures 52 and central boss 54 which receives permanent magnet 56.

- The valve 20 is closed when the ball 60 is located so as to seal the hole 36 in the sealing plate 34 so that no fluid may pass through the bore 44. In the preferred embodiment illustrated, the valve is held shut by virtue of magnet 28 holding the ball 60 in the closed position. It will be appreciated by those skilled in the art that other means for retaining ball 60 may be adopted.

When valve 20 is to be opened a direct current preferably in the form of a pulse may be applied to the solenoid (not shown) wound around bore 44 whereby to overcome the attractive magnetic force of the magnet 28 and push ball 60 towards magnet 56.

Valve 20 is open when the ball 60 is located so as to bear against the end cap 50. If the direct current pulse ceases, valve 20 is held open by virtue of magnet 56 holding ball 60 in the open position, although it will be appreciated by those skilled in the art that other means for retaining ball 60 may be adopted. For example, valve 20 may be held open by 5 maintaining the current through the solenoid.

When valve 20 is to be closed a direct current preferably in the form of a pulse may be applied to the solenoid in the opposite direction to the valve opening pulse so as to overcome the attractive magnetic force of magnet 56 and push ball 60 towards the closed position previously described.

10 It will be appreciated by those skilled in the art that valve 20 may be held closed by maintaining the current through the solenoid instead of, or in addition to, utilising the effect of magnet 28 on ball 60.

Figures 8 to 10 show another form of valve 100 suitable for mounting on curtain 16. As shown in Figure 8, valve 100 includes a casing 101 having a circular cylindrical outer 15 surface with inlet air holes 102, outlet air holes 103 and annular flange 104. In the preferred embodiment illustrated, the air holes are circular. However, they may take the form of slots or apertures of any suitable shape. Inlet air holes 102 and outlet air holes 103 are of sufficient size to allow adequate air flow through the valve when open. Valve 100 includes an end piece 105 which contains a central circular cylindrical boss 106 for 20 receiving magnet 107. It will be understood that the inlet air holes 102 may function as outlet air holes and the outlet air holes 103 may function as inlet air holes, depending on the direction of fluid flow through the valve.

Valve 100 includes a reel 108 provided with flanges 109 and 110 and a central circular bore 111 (the internal wall of which is shown in outline). Wire (not shown) is coiled 25 around the reel 108 between the flanges 109 and 110 to create a solenoid.

End piece 105 includes a central circular cylindrical tube 112. Bore 111 of reel 108 is fitted over tube 112 so that reel 108 is mounted on tube 112.

A circular cylindrical rod 113 is at least partially located inside tube 112. Rod 113 is linearly slidable within tube 112. Rod 113 is magnetic, ie is attracted by a magnet. Rod 30 113 carries panel 114 with annular sealing ring 115.

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Valve 100 contains a plate 116. As shown in Figures 8 and 10, plate 116 has air holes 117 and a central circular cylindrical boss 118 for receiving magnet 119.

As shown in Figure 9, valve 100 is closed when rod 113 is located such that sealing ring 115 on panel 114 sealingly abuts plate 116. In this configuration the valve is closed since

5 sealing ring 115 in combination with panel 114 prevents fluid passing through holes 117 and around panel 114 and thereby prevents fluid communication between holes 102 and holes 103. In the preferred embodiment illustrated, the valve is held shut by virtue of magnet 119 holding rod 113 in the closed position. It will be appreciated by those skilled in the art that other means for retaining the rod 113 may be adopted.

10 When valve 100 is to be opened a direct current preferably in the form of a pulse may be applied to the solenoid (not shown) wound around bore 111 of reel 108 whereby to overcome the attractive magnetic force of the magnet 119 and drive rod 113 towards magnet 107.

As shown in Figure 8, valve 100 is open when rod 113 is located such that sealing ring 115 15 on panel 114 is spaced from plate 116. In the preferred embodiment illustrated in Figure 8, magnet 107 is of sufficient strength, and rod 113 is within sufficient proximity of magnet 107 when valve 100 is in the open position, that, if the direct current pulse ceases, valve 100 is held open by virtue of magnet 107 holding rod 113 in the open position. However, it will be appreciated by those skilled in the art that other means for retaining rod 113 may 20 be adopted. For example, valve 100 may be held open by maintaining the current through the solenoid.

In the configuration shown in Figure 8, the valve is open since sealing ring 115 and panel 114 do not prevent fluid passing through holes 116 and around panel 113, thereby allowing fluid communication between holes 102 and holes 103.

25 When valve 100 is to be closed a direct current preferably in the form of a pulse may be applied to the solenoid in the opposite direction to the valve opening pulse so as to overcome the attractive magnetic force of magnet 107 and drive rod 113 towards the closed position previously described.

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It will be appreciated by those skilled in the art that valve 100 may be held closed by maintaining the current through the solenoid instead of, or in addition to, utilising the effect of magnet 119 on rod 113.

Figures 5 to 7 show an alternative form of valve 70 suitable for mounting on curtain 16 in 5 the same manner as described in relation to valve 100. Valve 70 has a base 72, having a hole typically oval or circular. Flap 74 is complementary to the hole in base 72. Seal 75 extends between base 72 and flap 74. Flap 74 is hingedly mounted on base 72 by hinge 76. Magnet 78 is mounted on flap 74. Attached to the base 72 is a coil 80 around a core 82 to form a solenoid.

10 A spacer 84 is attached to the centre of flap 74. Arm 86, carrying magnet 88, is mounted on spacer 84.

Spacer 84, arm 86, magnet 88, core 82 and coil 80 are protected by protective shield 91. Protective shield 91 contains airholes 92. Similarly magnet 78 is protected by shield 90.

In figure 7 valve 70 is shown in the closed position. In the preferred embodiment, valve 70 15 is held closed by the magnetic attraction between magnet 78 and core 82 of the solenoid, although it will be appreciated by those skilled in the art that other means for retaining flap 78 may be adopted.

' When valve 70 is to be opened, a direct current preferably in the form of a pulse may be applied to solenoid 80 so that core 82 repulses magnet 78 and attracts magnet 88. The 20 attraction of magnet 88 to core 82 drives arm 86 towards core 82 so as to move flap 74 away from seal 75 under the influence of hinge 76 and hence open valve 70. If the direct current pulse ceases valve 70 is held open by the magnetic attraction between magnet 88 and core 82. It will be appreciated by those skilled in the art that other means of retaining arm 86 may be adopted.

25 When valve 70 is to be closed a direct current or pulse may be applied to solenoid 80 in the opposite direction to the valve opening pulse so that core 82 repulses magnet 88 and attracts magnet 78. Valve 70 is then held closed as previously described.

In use, a prediction of the carbon dioxide level in the chamber based on the desired oxygen setpoint is made. The prediction is based on, amongst other things, the weight of the

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cargo, the temperature in the chamber, the time during which the cargo will be in transit, and the respiration quotient of the respiring produce.

- As the respiring produce will continue to consume oxygen and hence carbon dioxide will continue to be produced, a prediction is also made based on the desired carbon dioxide setpoint, that is, the difference between the predicted carbon dioxide level (based on the predicted rate of consumption of oxygen by the produce) and the desired level. Independent control of the carbon dioxide level is achieved by the bags of hydrated lime (9) of predetermined transmissibility to carbon dioxide in the chamber so as to absorb the difference between the predicted and desired levels.
- 5 10 After produce has been loaded into container 10 curtain 16 is installed thereby forming substantially sealed chamber 11. Chamber 11 is flushed with nitrogen to lower the initial oxygen concentration within the chamber to below a predetermined maximum oxygen concentration.
- During use, if controller 8 senses that the oxygen concentration within the chamber has fallen below a first predetermined minimum value, controller 8 sends a signal via wires 17 which causes valve 20 (whether functioning as inlet means or as outlet means) to open for a first predetermined length of time to drive chamber atmosphere out of the chamber, or to draw ambient atmosphere into the chamber, as the case may be, under the influence of the fan, so as to increase the oxygen concentration within chamber 11 as described.
- 15 20 Where valve 20 is being used as an outlet means, controller 8 opens valve 20 (on the high pressure side of the fan in chamber 11) following controller 8 sensing that the oxygen concentration in the chamber has fallen below a first predetermined minimum value. The fan forces chamber atmosphere out of the chamber through valve 20, thereby lowering the pressure in chamber 11 below atmospheric pressure. Ambient atmosphere is thus drawn into chamber 11 through leakage paths or holes, as described above, to increase the amount 25 of oxygen in chamber 11.
- Where valve 20 is being used as an inlet means, controller 8 opens valve 20 (now on the low pressure side of a fan in chamber 11) following controller 8 sensing that the oxygen concentration in the chamber has fallen below a first predetermined minimum value. The 30 oxygen concentration in chamber 11 is thereby increased. The increased pressure in

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chamber 11 forces chamber atmosphere out of chamber 11 through leakage paths or holes, as described above.

If, after valve 20 has closed, the oxygen concentration as measured by the sensor means has not increased to at least a second predetermined minimum value, controller 8 causes

- 5 valve 20 to switch to an open state for a second predetermined length of time so as to allow, in the manner described above, further air surrounding the chamber to enter chamber 11 and chamber atmosphere from within chamber 11 to exit chamber 11.

This process is repeated until the oxygen concentration has increased to an acceptable level.

- 10 If valves are used on curtain 16 as inlet means or outlet means in conjunction with a suitably placed source of high or low pressure (as the case may be), it is preferable to use valves 100 on curtain 16 rather than valves 70 since, as shown in Figure 8, valve 100 has air holes 102 and air holes 103 which are mounted on the side of the valve. This configuration prevents fluid passage through the valve from being impeded or prevented if  
15 the valve abuts door 14 or a surface within the chamber 11.

The apparatus provided by the present invention is relatively cheap to manufacture and install and can be installed in a variety of receptacles. The methods of atmosphere adjustment allow oxygen and carbon dioxide adjustment without any active monitoring of carbon dioxide levels or any associated active scrubbing of carbon dioxide from the  
20 chamber atmosphere.

The word 'comprising' and forms of the word 'comprising' as used in this description and in the claims does not limit the invention claimed to exclude any variants or additions. Modifications and improvements to the invention will be readily apparent to those skilled in the art. Such modifications and improvements are intended to be within the scope of this  
25 invention.

### Appendix

This Appendix details the derivation of equations for a continuous model of the chamber atmosphere. The assumptions on which this model is based are as follows:

1. The chamber atmosphere exiting the chamber through the outlet means is perfectly mixed (ie it is assumed that the proportions of constituent gases of the atmosphere exiting the chamber is equal to the proportions of constituent gases within the chamber).
- 5 2. The composition of the air entering the chamber through the inlet means consists of 21% oxygen and 79% nitrogen.
- 10 3. The rate of inflow of nitrogen is equal to the rate of outflow of nitrogen.
4. The system has reached equilibrium.

A diagrammatic representation of the model is given in Figure 11. The symbols will now be defined with reference to the model shown in the figure. The chamber is represented as 200. The inflow of nitrogen from ambient air is designated  $f_{1,N_2}$  and is shown as 206.

- 15 5. The inflow of oxygen from ambient air is designated  $f_{1,O_2}$  and is shown as 208. The outflow of nitrogen from chamber 200 is designated  $f_{2,N_2}$  and is shown as 210. The outflow of oxygen from chamber 200 is designated  $f_{2,O_2}$  and is shown as 212. The outflow of carbon dioxide from chamber 200 is designated  $f_{2,CO_2}$  and is shown as 214.

The total inflow rate (not shown) is designated  $f_{v_1}$  and represents the sum of  $f_{1,N_2}$  and  $f_{1,O_2}$ . The total outflow rate (not shown) is designated  $f_{v_2}$  and represents the sum of  $f_{2,N_2}$ ,  $f_{2,O_2}$  and  $f_{2,CO_2}$ .

The respiration produces 202 consumes oxygen at a flow rate represented by 216, designated  $r_{O_2}$  and produces carbon dioxide at a flow rate represented by 218, designated  $r_{CO_2}$ . Carbon dioxide removal means 204 removes carbon dioxide at a flow rate represented by 220 and designated  $a_{CO_2}$ .

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Inside the chamber, the oxygen concentration is designated  $p_{O_2}$  and is assumed to be at the setpoint because the system is assumed to have reached equilibrium. The nitrogen concentration is designated  $p_{N_2}$  and the carbon dioxide concentration is designated  $p_{CO_2}$ .

- 5 By definition, the sum of the concentrations in the chamber is unity:

$$(1) \quad p_{O_2} + p_{CO_2} + p_{N_2} = 1$$

It is assumed that the inflow of nitrogen is equal to the outflow of nitrogen:

$$\begin{aligned} f_{2,N_2} &= p_{N_2} f_{v2} \\ &= f_{1,N_2} \\ &= 0.79 f_{v1} \end{aligned}$$

Consequently:

$$10 \quad (2) \quad f_{v1} = \frac{p_{N_2}}{0.79} f_{v2}$$

The outflow of oxygen from the chamber is equal to the inflow of oxygen into the chamber less the rate of oxygen consumption through respiration:

$$f_{2,O_2} = f_{1,O_2} - r_{O_2}$$

Rearranging:

$$15 \quad (3) \quad \begin{aligned} f_{1,O_2} &= f_{2,O_2} + r_{O_2} \\ &= p_{O_2} f_{v2} + r_{O_2} \end{aligned}$$

The inflow of oxygen is the same proportion of the total inflow as the proportion of oxygen in air:

$$(4) \quad f_{1,O_2} = 0.21 f_{v1}$$

Setting the right hand side of (3) equal to the right hand side of (4) and rearranging:

$$20 \quad (5) \quad f_{v1} = \frac{p_{O_2} f_{v2} + r_{O_2}}{0.21}$$

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Setting the right hand side of (2) equal to the right hand side of (5):

$$\frac{p_{N_2}}{0.79} f_{v2} = \frac{p_{O_2} f_{v2} + r_{O_2}}{0.21}$$

Rearranging:

$$(6) \quad f_{v2} = \frac{0.79 r_{O_2}}{0.21 p_{N_2} - 0.79 p_{O_2}}$$

- 5 The total outflow is equal to the total inflow less the flow of oxygen consumed by respiration plus the flow of carbon dioxide produced by respiration less the removal of carbon dioxide by the carbon dioxide removal means:

$$(7) \quad f_{v2} = f_{v1} - r_{O_2} + r_{CO_2} - a_{CO_2}$$

Substituting (5) and (6) into (7) and solving for  $p_{CO_2}$ :

$$10 \quad (8) \quad p_{CO_2} = \frac{\left( \left( \frac{r_{CO_2}}{r_{O_2}} \right) - \left( \frac{a_{CO_2}}{r_{O_2}} \right) \right) (0.21 - p_{O_2})}{0.79 + 0.21 \left( \frac{r_{CO_2}}{r_{O_2}} \right) - 0.21 \left( \frac{a_{CO_2}}{r_{O_2}} \right)}$$

Noting that the quantity  $\left( \frac{r_{CO_2}}{r_{O_2}} \right)$  is the respiration quotient  $RQ$ , then equation (8) is as

follows when  $a_{CO_2}$  is zero (designated  $p_{CO_2}^*$ ):

$$(9) \quad p_{CO_2}^* = \frac{RQ \cdot (0.21 - p_{O_2})}{0.79 + 0.21 \cdot RQ}$$

Equation (8) may be rearranged to solve for  $a_{CO_2}$ :

$$15 \quad (10) \quad a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

Equation (10) may be recast as follows by substituting an expression involving  $p_{CO_2}^*$  for the expression  $(0.21 - p_{O_2})$ , and rearranging:

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$$(11) \quad \frac{a_{CO_2}}{r_{CO_2}} = \frac{(p_{CO_2}^* - p_{CO_2})(0.79 + 0.21RQ)}{p_{CO_2}^*(0.79 + 0.21RQ) - 0.21RQp_{CO_2}}$$

Equation (11) may be approximated as follows since the expression  $(0.79 + 0.21RQ)$  is generally close to unity:

$$(12) \quad \frac{a_{CO_2}}{r_{CO_2}} \approx \frac{p_{CO_2}^* - p_{CO_2}}{p_{CO_2}^* - 0.21RQp_{CO_2}}$$

- 5 Equation (12) shows how, as an approximation, the ratio of the rate of carbon dioxide absorption to the rate of carbon dioxide production varies as a function of the equilibrium carbon dioxide concentration in the absence of carbon dioxide absorption and the equilibrium carbon dioxide concentration with carbon dioxide absorption.

**The claims of the invention are as follows:**

1. A method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following step (b), the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter the chamber and an opening to permit chamber atmosphere to exit the chamber, the method comprising:
  - (a) monitoring the oxygen concentration within the chamber; and
  - (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing chamber atmosphere to exit the chamber through an opening so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening so that the amount of oxygen in the chamber is or will be increased.
2. A method according to claim 1 wherein the opening to permit chamber atmosphere to exit the chamber is the same opening as the opening to permit ambient atmosphere to enter the chamber.
3. A method according to claim 1 wherein the opening to permit ambient atmosphere to exit the chamber is an openable and closeable outlet means.
4. A method according to any one of the preceding claims wherein chamber atmosphere is caused to exit the chamber through the opening by locating the opening near a source of high pressure inside the chamber, such that chamber atmosphere is expelled from the chamber through the opening.
5. A method according to claim 4 wherein the source of high pressure is a fan.

6. A method according to claim 5 wherein the chamber is formed within a refrigerated container having a refrigeration fan inside the chamber, the refrigeration fan being the source of high pressure.
7. A method according to any one of claims 1 to 3 wherein chamber atmosphere is caused to exit the chamber through an opening by locating the opening near a source of low pressure outside the chamber, such that chamber atmosphere is drawn out of the chamber through the opening.
8. A method according to claim 7 wherein the source of low pressure is a fan.
9. A method according to any one of the preceding claims wherein an opening for permitting ambient atmosphere to enter the chamber is provided wholly or partly by leakage paths into the chamber.
10. A method according to claim 9 wherein the leakage path into the chamber comprises one or more holes in the chamber.
11. A method according to claim 9 wherein the opening comprises existing leakage paths into the chamber.
12. A method according to any one of claims 4 to 6 when depending from claim 2, wherein ambient atmosphere is drawn into the chamber through the opening following turning off the source of high pressure or removing the source of high pressure from the vicinity of the opening, so that when the pressure in the chamber is below ambient pressure, ambient atmosphere will be drawn into the chamber through the opening.
13. A method according to claim 7 or claim 8 when depending from claim 2, wherein ambient atmosphere is drawn into the chamber through the opening following turning off the source of low pressure or removing the source of low pressure from the vicinity of the opening, so that when the pressure in the chamber is below ambient pressure, ambient atmosphere will be drawn into the chamber through the opening.
14. A method according to any one of the preceding claims wherein sealing means are provided to seal the chamber to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen

into the chamber is less than the rate of consumption of oxygen by the respiring produce.

15. A method according to any one of the preceding claims, the method further comprising removing carbon dioxide from the chamber atmosphere substantially at a predetermined rate, the predetermined rate having been selected such that the carbon dioxide concentration within the chamber atmosphere does not substantially exceed a predetermined amount.
16. A method according to claim 15 wherein the predetermined carbon dioxide removal rate is calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere subject to the requirement that the oxygen concentration within the chamber be substantially maintained at a predetermined amount.
17. A method according to claim 16 wherein the predetermined carbon dioxide removal rate is calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

where  $a_{CO_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

20. A method according to any one of claims 15 to 17 wherein the carbon dioxide removal is effected by contacting a quantity of carbon dioxide absorbing material with the chamber atmosphere.
25. A method according to claim 18 wherein the carbon dioxide absorbing material is contained in at least one carbon dioxide transmissible container.
20. A method according to claim 19 wherein the at least one carbon dioxide transmissible container is selected so that the rate of carbon dioxide transmission

into the at least one carbon dioxide transmissible container is substantially equal to the predetermined carbon dioxide removal rate.

21. A method according to claim 3, or any one of claims 4 to 20 when depending from claim 3, wherein the outlet means is open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

- 5 22. A method for converting a receptacle into an adjusted atmosphere chamber for containing respiring produce, the method comprising:

(a) forming a chamber in the receptacle that is sealed to the extent that when the 10 pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of

consumption of oxygen by the respiring produce, and which is open to the extent that when the chamber pressure is less than ambient pressure following a chamber pressure reduction as described in step (e) the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce;

(b) optionally, installing sealing means so as to seal the chamber to the required extent;

(c) optionally, installing an opening in the chamber to permit ambient 20 atmosphere to enter the chamber;

(d) installing an opening to permit chamber atmosphere to exit the chamber;

(e) 25 installing a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause chamber atmosphere to exit the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening in the chamber so that the amount of oxygen in the chamber is or will be increased.

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23. A method according to claim 22 wherein the opening to permit chamber atmosphere to exit the chamber is the same as the opening to permit ambient atmosphere to enter the chamber.
24. A method according to claim 22 wherein the opening to permit chamber atmosphere to exit the chamber is an openable and closeable outlet means.
- 5 25. A method according to any one of claims 22 to 24 wherein the opening to permit chamber atmosphere to exit the chamber is located near a source of high pressure inside the chamber, or a source of low pressure outside the chamber.
26. A method according to claim 25 when depending from claim 24 wherein the 10 control means is adapted to cause chamber atmosphere to exit the chamber through the outlet means by opening the outlet means.
27. A method according to any one of claims 22 to 26 further comprising the step of 15 installing carbon dioxide removal means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate whereby the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce.
28. A method according to claim 27 wherein the predetermined carbon dioxide removal 20 rate is calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere when the chamber contains the respiring produce subject to the requirement that the oxygen concentration within the chamber be substantially maintained at a predetermined amount.
29. A method according to claim 28 wherein the predetermined carbon dioxide removal 25 rate is calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

where  $a_{O_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration

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within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

30. A method according to any one of claims 22 to 29 wherein the controller is adapted to open the outlet means for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.
31. A receptacle when converted into an adjusted atmosphere chamber in accordance with the method of any one of claims 22 to 30.
32. Apparatus for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following a chamber pressure reduction as described below, the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce, the apparatus comprising a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause chamber atmosphere to exit the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening in the chamber so that the amount of oxygen in the chamber is or will be increased.
33. Apparatus according to claim 32 comprising openable and closeable outlet means to permit chamber atmosphere to exit the chamber.
34. Apparatus according to claim 33 wherein the control means is adapted to cause the outlet means to open to cause chamber atmosphere to exit the chamber.
35. Apparatus according to any one of claims 32 to 34 further comprising a source of high pressure for locating inside the chamber to cause chamber atmosphere to exit the chamber.

36. Apparatus according to any one of claims 32 to 34 further comprising a source of low pressure for locating outside the chamber to cause chamber atmosphere to exit the chamber.
37. Apparatus according to any one of claims 32 to 36 further comprising sealing means for sealing the chamber to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce.
38. Apparatus according to any one of claims 32 to 37 comprising carbon dioxide reduction means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate so that the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce.
39. Apparatus according to claim 33, or to any one of claims 34 to 38 when depending from claim 33, wherein the controller is further adapted to cause the outlet means to remain open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.
40. Apparatus according to claim 33, or to any one of claims 34 to 39 when depending from claim 33, wherein the outlet means comprise one or more electromagnetically actuatable valves having a solenoid so that the one or more valves may be opened from a closed position and closed from an open position by applying direct electric current to the solenoid, the one or more valves being held in either the open position or the closed position in the absence of the application of the direct electric current.
41. A method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber being open to the extent that when the chamber pressure is less than ambient pressure following step (b), the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce,

the chamber having an opening to permit ambient atmosphere to enter the chamber, and an opening to permit chamber atmosphere to exit the chamber, the method comprising:

- (a) monitoring the oxygen concentration within the chamber;
  - 5 (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing chamber atmosphere to exit the chamber through an opening so that the pressure in the chamber is or will be reduced below ambient pressure such that ambient atmosphere is or will be drawn into the chamber through an opening so that the amount of oxygen in 10 the chamber is or will be increased; and
  - (c) prior to steps (a) and (b), selecting an oxygen setpoint such that steps (a) and (b) cause the carbon dioxide concentration within the chamber atmosphere to not substantially exceed a predetermined amount.
42. A method according to claim 41 wherein the opening for permitting chamber 15 atmosphere to exit the chamber is an openable and closeable outlet means.
43. A method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen 20 into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter the chamber, and an opening to permit chamber atmosphere to exit the chamber, the method comprising:
- (a) monitoring the oxygen concentration within the chamber; and
  - 25 (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing ambient atmosphere to enter the chamber through an opening so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening;

the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following step (b) the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber again falls below the predetermined amount, to a level that will not prevent ambient atmosphere from entering the chamber through the opening first referred to in step (b).

- 5            44. A method according to claim 43 wherein the opening to permit ambient atmosphere to enter the chamber is the same opening as the opening to permit chamber atmosphere to exit the chamber.
- 10          45. A method according to claim 43 wherein the opening to permit ambient atmosphere to enter the chamber is an openable and closeable inlet means.
- 15          46. A method according to any one of claims 43 to 45 wherein chamber atmosphere is caused to enter the chamber through an opening by locating the opening near a source of low pressure inside the chamber, such that chamber atmosphere is drawn into the chamber through the opening.
47. A method according to claim 46 wherein the source of low pressure is a fan.
48. A method according to claim 47 wherein where the chamber is formed within a refrigerated container having a refrigeration fan inside the chamber, the refrigeration fan being the source of low pressure.
- 20          49. A method according to any one of claims 43 to 45 wherein chamber atmosphere is caused to enter the chamber through an opening by locating the opening near a source of high pressure outside the chamber, such that chamber atmosphere is forced into the chamber through the opening.
50. A method according to claim 49 wherein the source of high pressure is a fan.
- 25          51. A method according to any one of claims 43 to 50 wherein an opening for permitting chamber ambient atmosphere to exit the chamber is provided wholly or partly by leakage paths out of the chamber.
52. A method according to claim 51 wherein the leakage path out of the chamber comprises one or more holes in the chamber.

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53. A method according to claim 51 wherein the opening comprises existing leakage paths out of the chamber.
54. A method according to any one of claims 46 to 48 when depending from claim 44, wherein ambient atmosphere is caused to enter the chamber through the opening following turning off the source of low pressure or removing the source of low pressure from the vicinity of the opening, so that when the pressure in the chamber is above ambient pressure, chamber atmosphere will be forced out of the chamber through the opening.
55. A method according to claim 49 or claim 50 when depending from claim 44, wherein ambient atmosphere is caused to enter the chamber through the opening following turning off the source of low pressure or removing the source of high pressure from the vicinity of the opening, so that when the pressure in the chamber is above ambient pressure, chamber atmosphere will be forced out of the chamber through the opening.
- 10 56. A method according to any one of claims 43 to 55 wherein sealing means are provided to seal the chamber to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiration produce.
- 15 57. A method according to any one of claims 43 to 56, the method further comprising the step of removing carbon dioxide from the chamber atmosphere substantially at a predetermined rate, the predetermined rate having been selected such that the carbon dioxide concentration within the chamber atmosphere does not substantially exceed a predetermined amount.
- 20 58. A method according to claim 57 wherein the predetermined carbon dioxide removal rate is calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere subject to the requirement that the oxygen concentration within the chamber be substantially maintained at a predetermined amount.

59. A method according to claim 58 wherein the predetermined carbon dioxide removal rate is calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

5 where  $a_{CO_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

60. A method according to any one of claims 57 to 59 wherein the carbon dioxide removal is effected by contacting a quantity of carbon dioxide absorbing material with the chamber atmosphere.

61. A method according to claim 60 wherein the carbon dioxide absorbing material is contained in at least one carbon dioxide transmissible container.

62. A method according to claim 61 wherein the at least one carbon dioxide transmissible container is selected so that the rate of carbon dioxide transmission into the at least one carbon dioxide transmissible container is substantially equal to the predetermined carbon dioxide removal rate.

63. A method according to claim 45, or any one of claims 46 to 62 when depending from claim 45, wherein the outlet means is open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

64. A method for converting a receptacle into an adjusted atmosphere chamber for containing respiring produce, the method comprising:

(a) forming a chamber in the receptacle that is sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, and which is open to the extent that when the chamber pressure is greater than ambient pressure

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- following a chamber pressure increase as described in step (e) the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber falls below the predetermined amount described in step (e), to a level that will not prevent ambient atmosphere from entering into the chamber through the opening referred to in step (c);
- (b) optionally, installing sealing means so as to seal the chamber to the required extent;
- (c) installing an opening in the chamber to permit ambient atmosphere to enter the chamber;
- (d) optionally, installing an opening in the chamber to permit chamber atmosphere to exit the chamber;
- (e) installing a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause ambient atmosphere to enter the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening in the chamber.
65. A method according to claim 64 wherein the opening to permit ambient atmosphere to enter the chamber is the same as the opening to permit chamber atmosphere to exit the chamber.
- 25 66. A method according to claim 64 wherein the opening to permit ambient atmosphere to enter the chamber is an openable and closeable inlet means.
67. A method according to any one of claims 64 to 66 wherein the opening to permit ambient atmosphere to enter the chamber is located near a source of low pressure inside the chamber, or a source of high pressure outside the chamber.

68. A method according to claim 67 when depending from claim 66 wherein the control means is adapted to cause chamber atmosphere to enter the chamber through the inlet means by opening the inlet means.
69. A method according to any one of claims 64 to 68 further comprising the step of installing carbon dioxide removal means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate whereby the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce.
70. A method according to claim 69 wherein the predetermined carbon dioxide removal rate is calculated from a formula derived from a mathematical model of the proportions of the chamber atmosphere when the chamber contains the respiring produce subject to the requirement that the oxygen concentration within the chamber be substantially maintained at a predetermined amount.
71. A method according to claim 70 wherein the predetermined carbon dioxide removal rate is calculated from a formula that produces a result substantially equal to the result produced by a calculation in accordance with the following formula:

$$a_{CO_2} = r_{CO_2} - \frac{0.79 p_{CO_2} r_{O_2}}{(0.21 - p_{O_2}) - 0.21 p_{CO_2}}$$

where  $a_{O_2}$  is the carbon dioxide removal rate;  $p_{O_2}$  is the oxygen setpoint, expressed as a proportion;  $p_{CO_2}$  is the desired carbon dioxide concentration within the chamber, expressed as a proportion;  $r_{O_2}$  is the respiration rate; and  $r_{CO_2}$  is the rate of production of carbon dioxide through respiration.

72. A method according to any one of claims 64 to 72 wherein the controller is adapted to open the outlet means for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint
73. A receptacle when converted into an adjusted atmosphere chamber in accordance with the method of any one of claims 64 to 73.

74. Apparatus for adjusting the atmosphere within a chamber containing respiration produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiration produce, the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following a chamber pressure increase as described below, the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber falls below the predetermined amount described below, to a level that will not prevent ambient atmosphere from entering the chamber through an opening, the apparatus comprising a controller having an oxygen concentration sensor and control means responsive to the oxygen concentration sensor, the control means being adapted to cause ambient atmosphere to enter the chamber following the oxygen concentration sensor detecting that the oxygen concentration in the chamber has fallen below a predetermined amount so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening in the chamber.
75. Apparatus according to claim 74 comprising openable and closeable inlet means to permit chamber atmosphere to enter the chamber.
76. Apparatus according to claim 75 wherein the control means is adapted to cause the inlet means to open to allow chamber atmosphere to enter the chamber.
77. Apparatus according to any one of claims 74 to 76 further comprising a source of low pressure inside the chamber to cause ambient atmosphere to enter the chamber.
78. Apparatus according to any one of claims 74 to 76 further comprising a source of high pressure outside the chamber to cause ambient atmosphere to enter the chamber.
79. Apparatus according to any one of claims 74 to 78 further comprising sealing means for sealing the chamber to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen

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into the chamber is less than the rate of consumption of oxygen by the respiring produce.

- 5        80. Apparatus according to any one of claims 74 to 79 comprising carbon dioxide reduction means adapted to remove carbon dioxide from the chamber atmosphere substantially at a predetermined rate so that the carbon dioxide concentration within the chamber atmosphere will not substantially exceed a predetermined amount when the chamber contains the respiring produce.

10      81. Apparatus according to claim 75, or to any one of claims 76 to 80 when depending from claim 75, wherein the controller is further adapted to cause the inlet means to remain open for a time that is approximately proportional to the difference between the detected oxygen concentration and an oxygen setpoint.

15      82. Apparatus according to claim 75, or to any one of claims 76 to 81 when depending from claim 75, wherein the inlet means comprise one or more electromagnetically actuatable valves having a solenoid so that the one or more valves may be opened from a closed position and closed from an open position by applying direct electric current to the solenoid, the one or more valves being held in either the open position or the closed position in the absence of the application of the direct electric current.

20      83. A method for adjusting the atmosphere within a chamber containing respiring produce, the chamber being sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce, the chamber having an opening to permit ambient atmosphere to enter the chamber, and an opening to permit chamber atmosphere to exit the chamber, the method comprising:

25                  (a) monitoring the oxygen concentration within the chamber;

                        (b) following detection that the oxygen concentration in the chamber has fallen below a predetermined amount, causing ambient atmosphere to enter the chamber through an opening so that the amount of oxygen in the chamber is or will be increased and so that the pressure in the chamber is or will be

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increased above ambient pressure such that chamber atmosphere is or will be expelled from the chamber through an opening; and

- (c) prior to steps (a) and (b), selecting an oxygen setpoint such that steps (a) and (b) cause the carbon dioxide concentration within the chamber atmosphere to not substantially exceed a predetermined amount,

5 the chamber being open to the extent that when the chamber pressure is greater than ambient pressure following step (b) the rate of leakage of chamber atmosphere out of the chamber is sufficient to reduce the chamber pressure, before the oxygen concentration in the chamber again falls below the predetermined amount, to a level that will not prevent ambient atmosphere from being drawn into the chamber through the opening first referred to in step (b).

10 84. A method according to claim 83 wherein the opening for permitting chamber atmosphere to enter the chamber is an openable and closeable inlet means.

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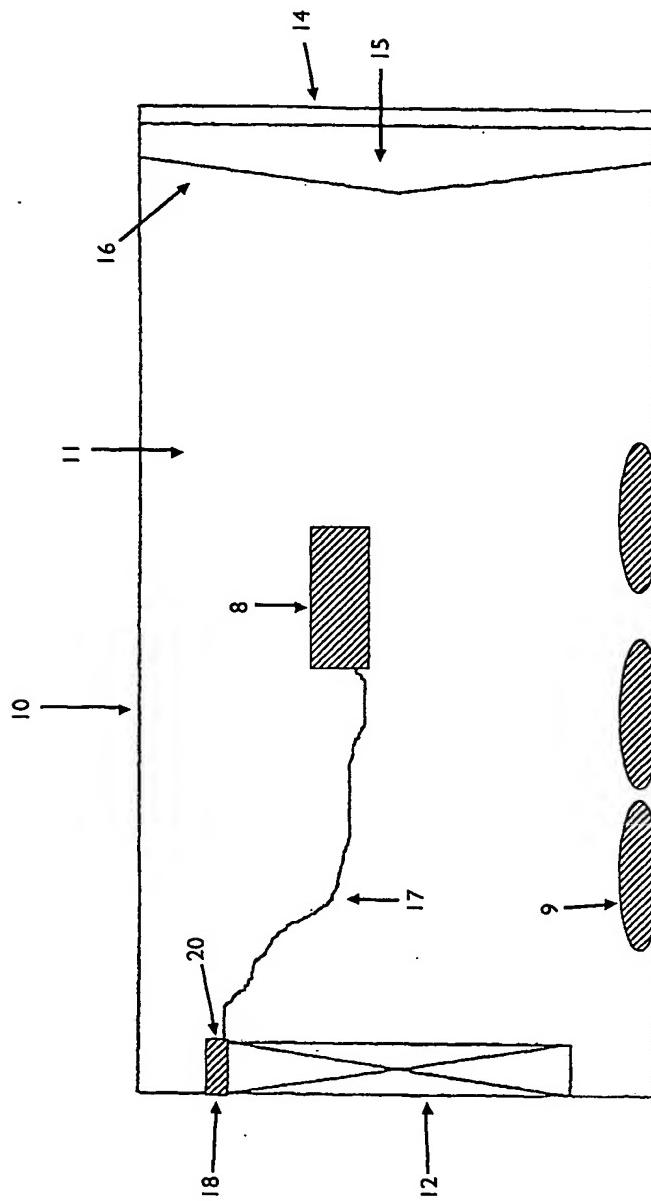


FIG 1

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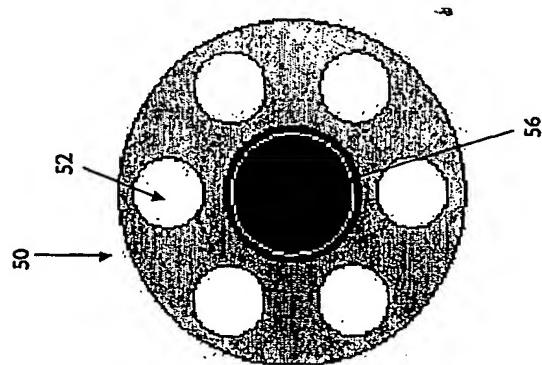


FIG 4

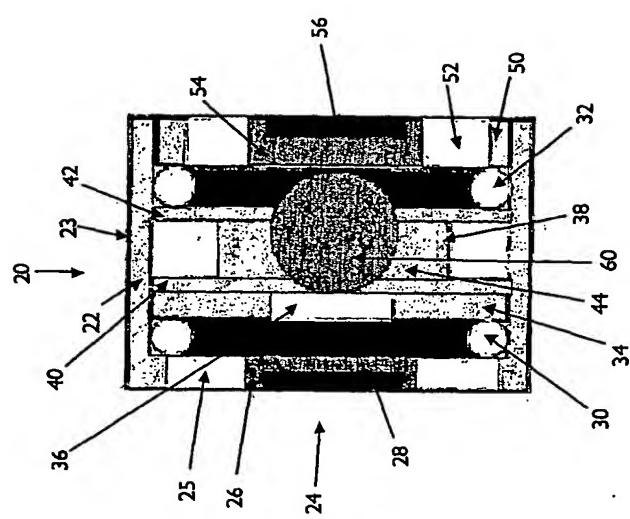


FIG 2

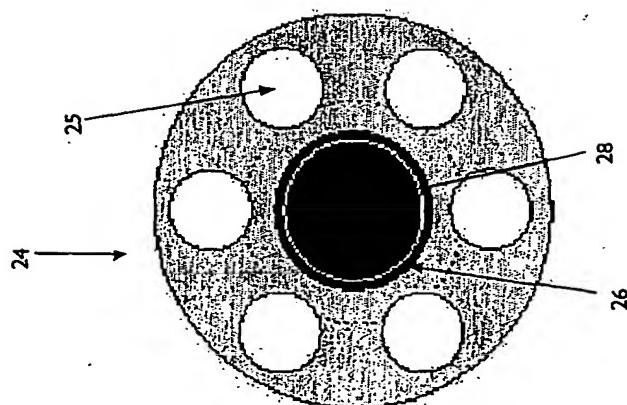


FIG 3

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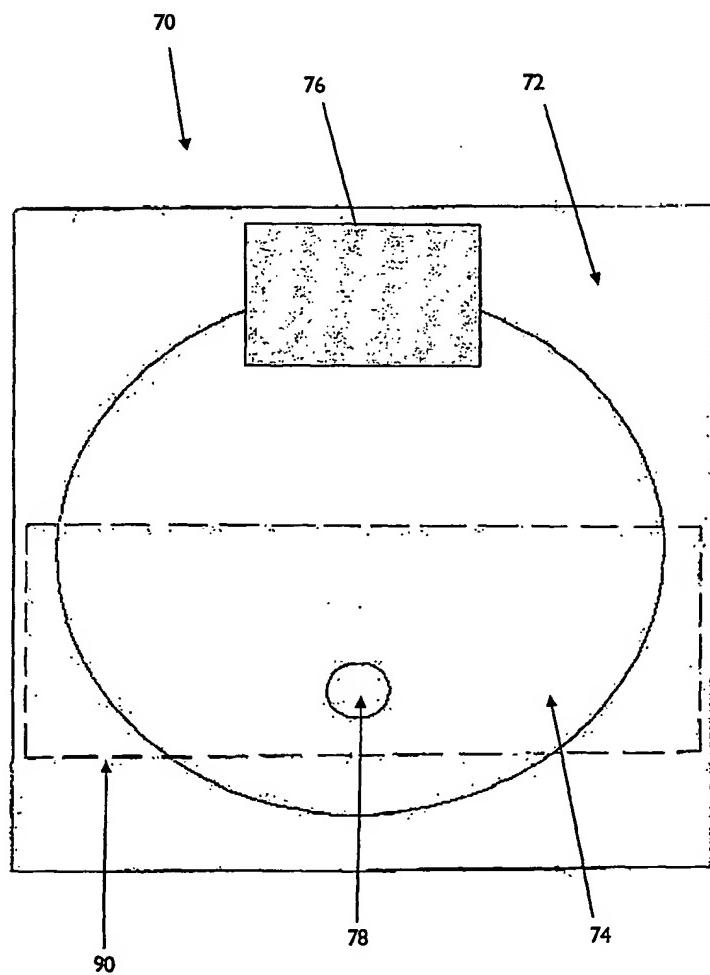


FIG 5

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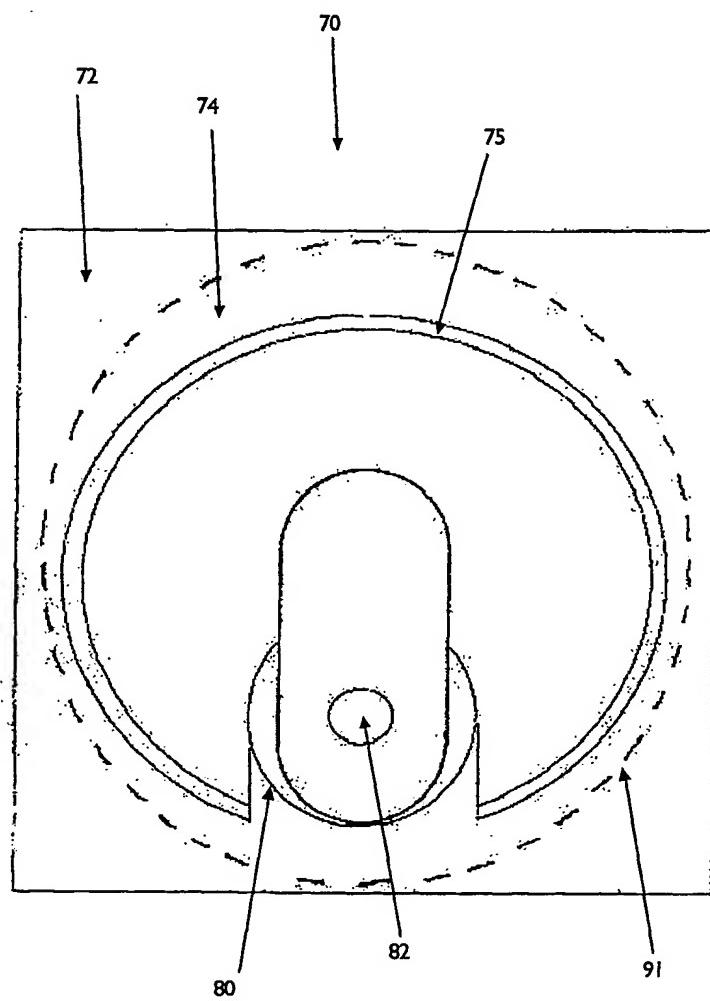


FIG 6

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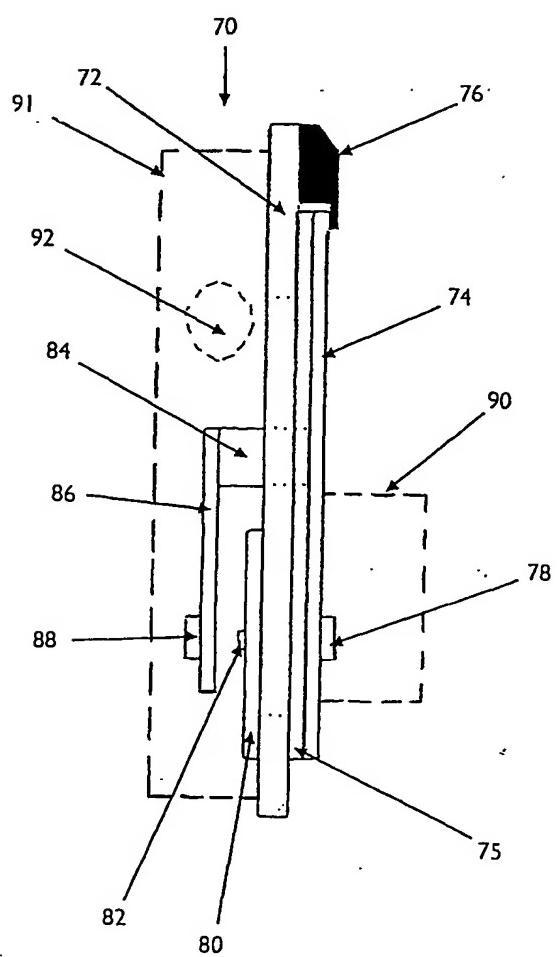


FIG 7

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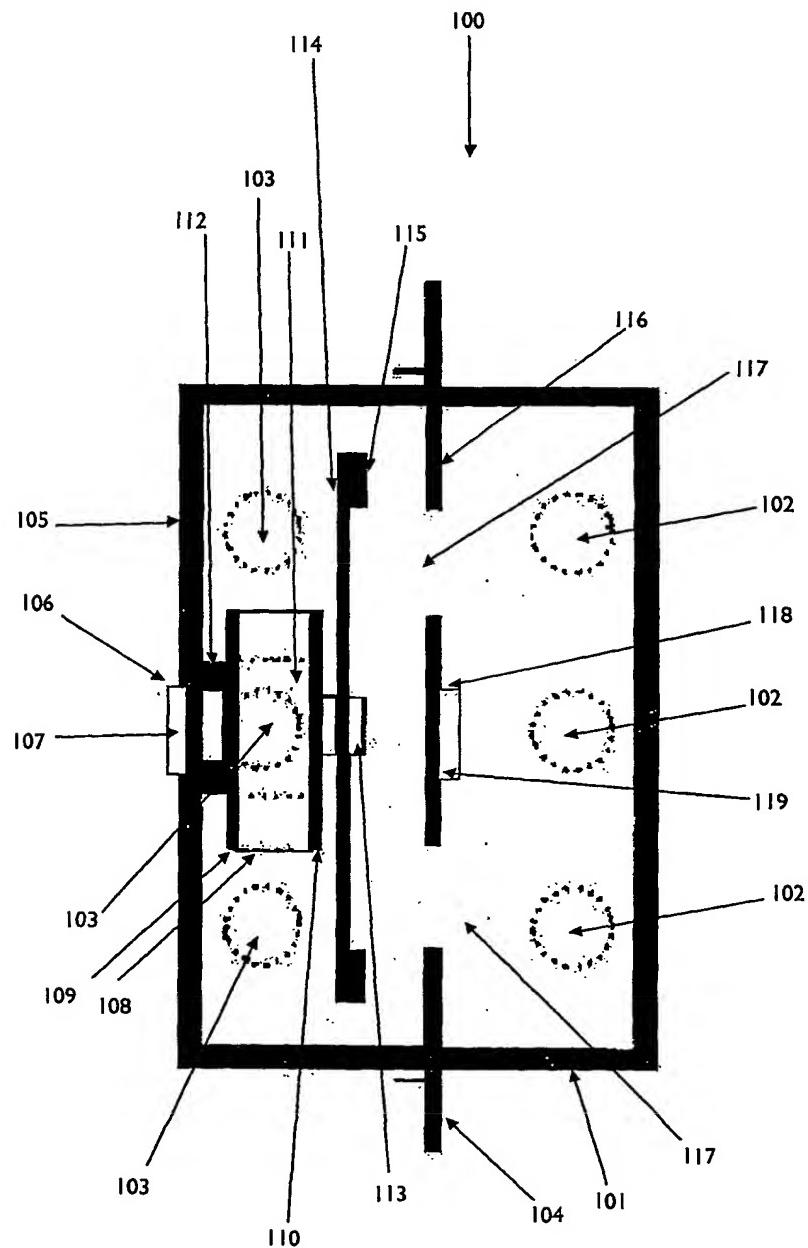


FIG 8

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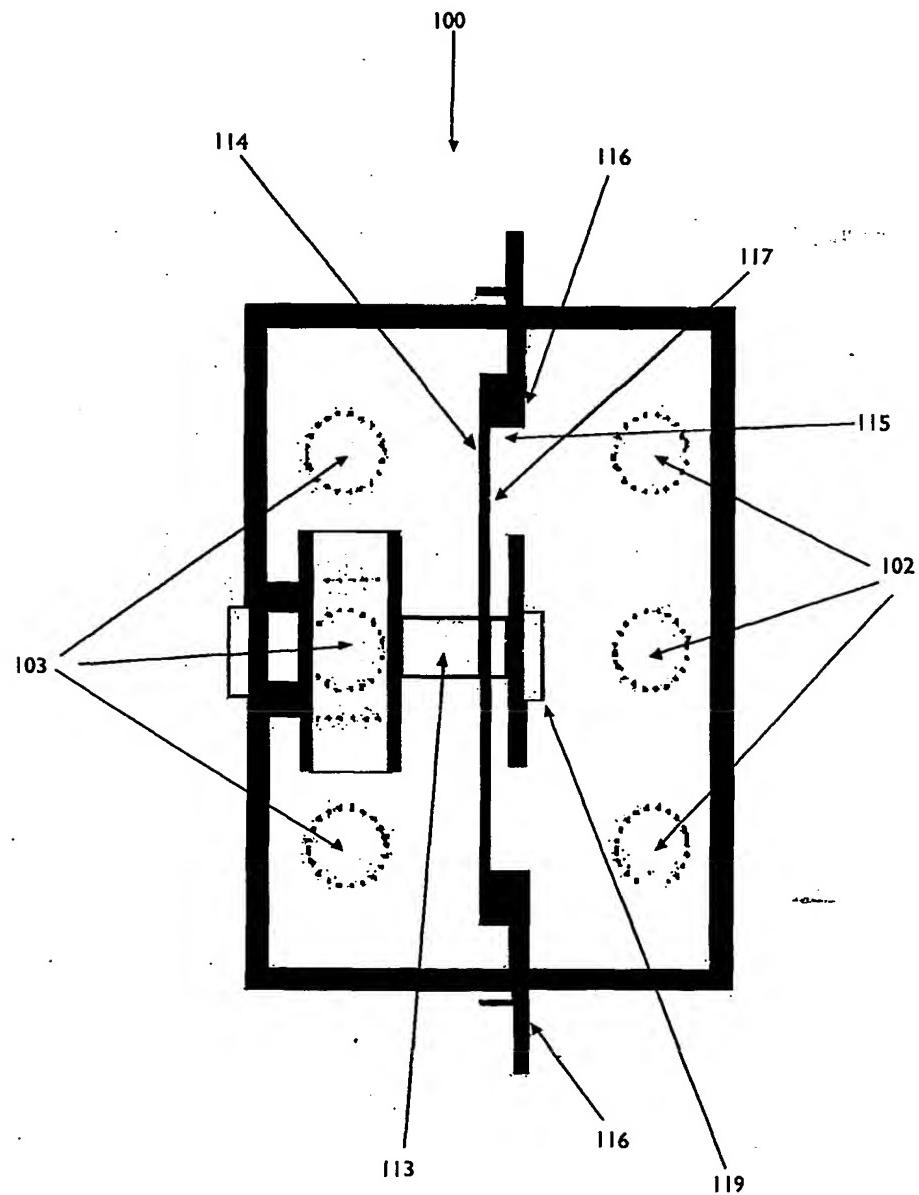


FIG 9

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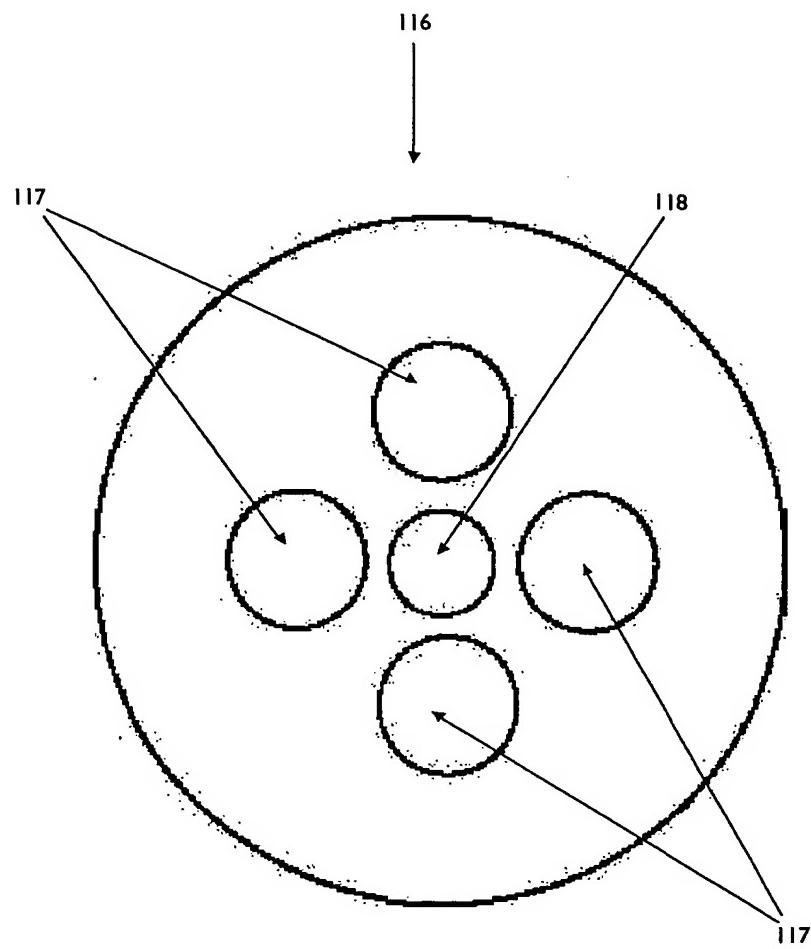
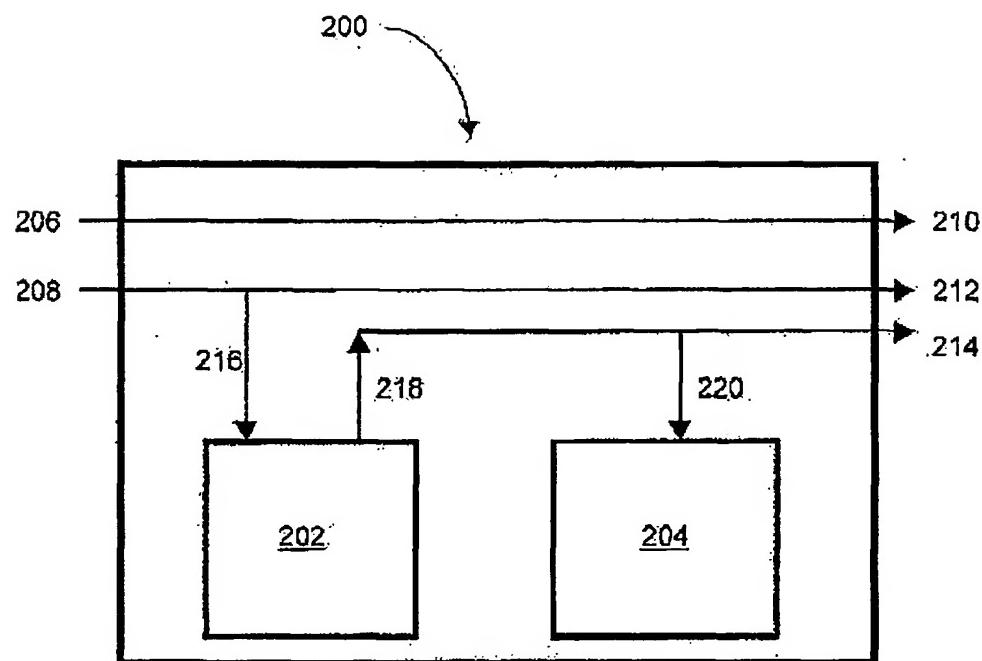


FIG 10

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| INTERNATIONAL SEARCH REPORT  |  | International application No.<br><b>PCT/AU01/00487</b>  |
|--|--|---|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b>   |  |   |
| Int. Cl. 7: B65D 81/24, 85/50, 88/74, A23L 3/3418, A23B 7/148  |  |   |
| According to International Patent Classification (IPC) or to both national classification and IPC  |  |   |
| <b>B. FIELDS SEARCHED</b>  |  |   |
| Minimum documentation searched (classification system followed by classification symbols)<br>IPC REFER ELECTRONIC DATABASE CONSULTED BELOW   |  |   |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  |  |   |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>DWPI IPC B65B, B65D, A23L, F24F, F25J, A61L 9/-, B60H, B60P, A01G & keywords: oxygen, control, respiration, fruit, atmosphere, pressure, sense, ship, setpoint, opening and similar terms  |  |   |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>  |  |   |
| Category*  | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.                                   |
| X<br>Y   | WO 00/23350 A (MITSUBISHI AUSTRALIA LTD) 27 April 2000<br>See whole document - Similar specification to present application.<br>See whole document                       | 1-84<br>2-21, 23-31, 33-40, 42, 44-63, 65-73, 75-82, 84 |
| X<br>Y   | EP 353021 B (TRANSFRESH CORPORATION) 31 March 1993<br>See whole document<br>See whole document   | 1-84<br>2-21, 23-31, 33-40, 42, 44-63, 65-73, 75-82, 84 |
| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C <input checked="" type="checkbox"/> See patent family annex  |  |   |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed |  |   |
| Date of the actual completion of the international search<br><b>29 June 2001</b>   | Date of mailing of the international search report<br><b>10 July 2001</b>  |   |
| Name and mailing address of the ISA/AU<br><br>AUSTRALIAN PATENT OFFICE<br>PO BOX 200, WODEN ACT 2606, AUSTRALIA<br>E-mail address: pct@ipaaustralia.gov.au<br>Facsimile No. (02) 6285 3929   | Authorized officer<br><br><b>ADRIANO GIACOBETTI</b><br>Telephone No : (02) 6283 2579 |   |

| INTERNATIONAL SEARCH REPORT                                  |   | International application No.<br><b>PCT/AU01/00487</b> |
|--|---|--|
| <b>C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT</b> |   |  |
| Category*  | Citation of document, with indication, where appropriate, of the relevant passages                  | Relevant to claim No.                                  |
| X  | EP 136042 B (TRANSFRESH CORPORATION) 8 January 1992<br>See whole document                           | 1-84   |
| Y  | See whole document  | 2-21, 23-31, 33-40, 42,<br>44-63, 65-73, 75-82, 84     |
| X  | US 5872721 A (HUSTON et al) 16 February 1999<br>See whole document                                  | 43-84  |
| Y  | See whole document  | 44-63, 65-73, 75-82, 84                                |
| X  | US 5156009 A (WOODRUFF) 20 October 1992<br>See whole document                                       | 43-84  |
| Y  | See whole document  | 44-63, 65-73, 75-82, 84                                |
| X  | WO 91/11913 A (THE BROKEN HILL PROPRIETARY COMPANY<br>LIMITED) 22 August 1991<br>See whole document | 43-84  |
| Y  | See whole document  | 44-63, 65-73, 75-82, 84                                |
| X  | US 5457963 A (CAHILL-O'BRIEN et al) 17 October 1995<br>See whole document                           | 43-84  |
| Y  | See whole document  | 44-63, 65-73, 75-82, 84                                |
| X  | US 5799495 A (GAST, JR et al) 1 September 1998<br>See whole document                                | 43-84  |
| Y  | See whole document  | 44-63, 65-73, 75-82, 84                                |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/00487

**Box I Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos :  
because they relate to subject matter not required to be searched by this Authority, namely:
  
  
  
2.  Claims Nos :  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
  
  
3.  Claims Nos :  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

**Box II Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

See supplemental sheet

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
  
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

The additional search fees were accompanied by the applicant's protest

No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU01/00487

**Supplemental Box**

(To be used when the space in any of Boxes I to VIII is not sufficient)

**Continuation of Box No: II**

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority has found that there are two different inventions as follows:

1. Claims 1 to 21, 22 to 31, 41 and 42 relate to a method (or apparatus) for adjusting the atmosphere within a chamber containing respiring produce. When the pressure within the chamber is less than ambient pressure following step (b) below, the rate of entry of oxygen into the chamber is greater than the rate of consumption of oxygen by the respiring produce. The method comprises the steps of (a) monitoring the oxygen concentration within the chamber, and (b) following detection that the oxygen concentration has fallen below a predetermined amount, causing chamber atmosphere to exit the chamber through an opening so that the pressure in the chamber is reduced below ambient pressure such that ambient atmosphere will be drawn through an opening into the chamber. It is considered that the particular features of the rate of oxygen entry being greater than the rate of oxygen consumption and the causing of the chamber pressure to be reduced below ambient pressure to cause the drawing of ambient atmosphere into the chamber comprise a first "special technical feature".
2. Claims 43 to 63, 64 to 73, 74 to 82, 83 and 84 relate to a method (or apparatus) for adjusting the atmosphere within a chamber for containing respiring produce. The method (or apparatus) comprises monitoring the oxygen concentration within the chamber and, if the oxygen concentration has fallen below a predetermined amount, to cause ambient atmosphere to enter the chamber so that the amount of oxygen in the chamber is increased. The chamber pressure will also be increased above ambient pressure such that chamber atmosphere will be expelled from the chamber through an opening. It is considered that the features of the method or apparatus causing ambient atmosphere to enter into the chamber and increase the chamber pressure when oxygen concentration is detected to be below a predetermined amount and then expelling some of the chamber atmosphere through an opening comprise a second "special technical feature".

The features common to all of the independent claims 1, 22, 32, 41, 43, 64, 74 and 83 is a method of adjusting the atmosphere within a chamber which is used for containing respiring produce. The chamber is sealed to the extent that when the pressure within the chamber is substantially equal to ambient pressure the rate of leakage of oxygen into the chamber is less than the rate of consumption of oxygen by the respiring produce. The oxygen concentration within the chamber is monitored and, if the concentration is below a predetermined amount, to cause to enter into the chamber some ambient atmosphere so that the amount of oxygen in the chamber is increased. However these common features are considered to be generic in this well traversed art, and not novel in light of the following examples of prior art documents:

- (a) US 5872721 A (HUSTON et al) 16 February 1999 (Note the extensive listing of prior art documents)
- (b) US 5438841 A (CAHILL-O'BRIEN et al) 8 August 1995 (Method)
- (c) US 5515693 A (CAHILL-O'BRIEN et al) 14 May 1996 (Apparatus)
- (d) US 5156009 A (WOODRUFF) 20 October 1992 (Method)
- (e) US 5063753 A (WOODRUFF) 12 November 1991 (Apparatus)

These documents disclose arrangements for controlling and modifying the atmosphere of a chamber for storing respiring produce. A sensor means is provided to monitor the level of oxygen concentration within the chamber and a controller to increase the amount of oxygen in the chamber when the concentration falls below a predetermined amount.

Consequently the common feature does not constitute "a special technical feature" within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art. Since there exists no other common feature which can be considered as a special technical feature within the meaning of PCT Rule 13.2, second sentence, no technical relationship within the meaning of PCT Rule 13 between the different inventions can be seen. Consequently it appears that *a posteriori*, the claims do not satisfy the requirement of unity of invention.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
**PCT/AU01/00487**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent Document Cited in<br>Search Report |          |      | Patent Family Member |    |           |    |         |
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| END OF ANNEX                              |          |      |                      |    |           |    |         |